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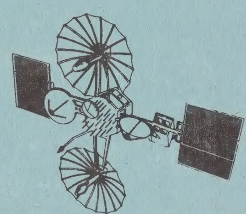
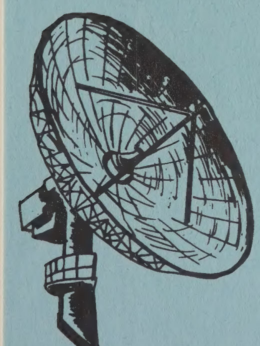
RX-4200 USER'S MANUAL

COMPLETE DETAILS ON FABRICATING A FULLY TUNABLE SATELLITE VIDEO RECEIVER FROM STANDARD MICROCOMM CIRCUIT MODULES

TO COOP,
WHO STARTED
THE INDUSTRY -
WARMEST 73,
Paul





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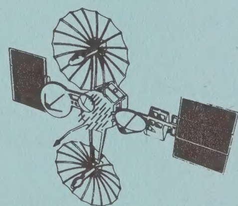

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LIST OF TABLES, FIGURES, AND DIAGRAMS

CONTENTS

SECTION 1

OVERVIEW

INTRODUCTION

This Manual details the design, construction and application of a set of microwave circuit modules known as the RX-4200 Module Set, from which a fully tunable 24-channel video receiver can be assembled to tune the downlink passbands of the half dozen Domestic Communications Satellites (DOMSATs) currently serving the North American continent. Although the RX-4200 Module Set may be employed in other services (including audio and data reception, INTELSAT reception, terrestrial microwave links, etc.), the design of the modules has been specifically optimized to provide a low cost, high performance receiver package for the private Television Receive Only (TVRO) earthstation, operating in the 3.7 to 4.2 GHz band.

The RX-4200 Module Set is provided primarily to space communications experimenters wishing to assemble their own receivers from commercial tuned and tested microwave circuit modules. Those potential earthstation owners lacking technical backgrounds are advised that interfacing the assembled modules and constructing the required ancillary circuits are tasks for a skilled electronics technician. Non-technical satellite video enthusiasts would do well to consider purchasing one of the many complete, commercially assembled DOMSAT video receivers now available. The ICM Model TV-4200 Video Satellite Receiver, which may be ordered directly from Microcomm, is a consumer-oriented product based upon the RX-4200 modular design, and is highly recommended by Microcomm's engineering staff. A preliminary data sheet on this receiver is included at the end of this Section.

SCOPE

This User's Manual contains schematic diagrams, parts lists, circuit descriptions and circuit board layouts for the RX-4200 Modules, as well as applications information related to interfacing them into a complete, frequency agile video receiver. However, it must be emphasized that this Manual is not intended to serve as project documentation for those experimenters wishing to duplicate the modules themselves, though a skilled microwave technician with a properly equipped laboratory could no doubt do so. Rather, the information provided in the Manual is intended to assist those purchasing the complete RX-4200 Module Set in properly interfacing, maintaining, operating and troubleshooting their purchased Modules.

This must not be considered a project construction manual, nor is it recommended that duplication of these modules be attempted, because of the inordinate amount of specialized test equipment required to properly tune, test and optimize the circuit modules (see the Recommended Equipment List, Table RX-4200-905, on the following page). It is obviously

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

INSTRUMENT TYPE	RECOMMENDED MFGR/MODEL	COST (APPROX.)
Display Mainframe	Hewlett-Packard 182T	$2000
Spectrum Analyzer Plug-In	Hewlett-Packard 8559A	$7600
Network Analyzer Plug-In	Hewlett-Packard 8755A	$1800
Coaxial Detector	Hewlett-Packard 11664A	$ 300
PIN Diode Modulator	Hewlett-Packard 11665A	$ 500
Reflectometer Bridge	Hewlett-Packard 11666A	$2600
Sweep Generator Mainframe	Wiltron 610D	$1700
Sweep Generator Plug-In Oscillator	Wiltron 6213D	$5400
Microwave Frequency Counter	Racal/Dana 9921	$2200
Microwave Power Meter	Hewlett-Packard 435A	$1000
Power Sensor	Hewlett-Packard 8481A	$ 500
Oscilloscope Vertical Amplifier	Hewlett-Packard 1805A	$1600
Oscilloscope Time Base Plug-In	Hewlett-Packard 1825A	$1000
Dual Variable Power Supply	Hewlett-Packard 6205B	$ 400

NOTE: The above equipment, or equivalent, is recommended for in-plant production testing, tune-up and system troubleshooting of receivers incorporating the RX-4200 Module Set. It is not required to assemble a working receiver from commercially supplied, tuned and tested modules. See text.

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APPROVALS	DATE
SS	9-74

RX-4200 Production Testing
RECOMMENDED EQUIPMENT

SIZE	CODE IDENT NO.	DRAWING NO.
		RX-4200-905
SCALE		SHEET 1 OF 1

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impractical for the experimenter to purchase nearly $30,000 in microwave test instrumentation merely to duplicate a module set which can be purchased, completely tuned and tested, for $1000.

On the other hand, there are those serious microwave experimenters who indeed have access to a properly equipped laboratory, and who wish to assemble their own circuit modules as a learning experience. In order to promote such activities, Microcomm's Chief Engineer H. Paul Shuch will continue his practice of publishing these designs as complete construction articles in various Amateur Radio periodicals. If you are a home constructor with access to the required test equipment, watch for his articles in upcoming issues of Ham Radio and 73 Magazines. It should be pointed out, however, that Microcomm is in no position to offer printed circuit boards or kits of parts for these modules, the current market demand being more than adequate to totally exhaust our available boards and components at this time. Similarly, the demand for complete module sets is such that we are no longer able to sell modules individually. We regret any inconvenience which these restrictions will doubtless cause the legitimate microwave experimenter, but are confident that persistence and ingenuity on the part of the dedicated hobbyists will prevail.

MODULE SPECIFICATIONS

The RX-4200 Module Set consists of six circuit assemblies, from which a dual-conversion superheterodyne microwave receiver can be assembled. Collectively the Modules represent both double-balanced Mixers, both Local Oscillators (one tuned, the other crystal controlled), and all necessary IF amplifiers and filters. Specifications for the individual modules are shown in the Data Sheet on the following page. On the reverse of the Data Sheet is a block diagram detailing the manner in which the individual modules are interfaced.

Please note that all prices and specifications shown on the Data Sheet are subject to change without notice.

For those desiring access to detailed design considerations for these modules, Microcomm's Application Note #8, titled "A Low-Cost Modular Receiver for DOMSAT Video" is available for $1.00 U. S. plus a stamped, self-addressed envelope.

SYSTEM REQUIREMENTS

In addition to a tunable video receiver, assembly of a TVRO earthstation requires a low-noise preamplifier and a high-gain antenna. Selection of these system components is detailed in Microcomm's Application Note #4, titled "Antenna/LNA Tradeoff Analysis for C-Band Video Terminals". Reprints are available for $1.00 U. S. plus a stamped, self-addressed envelope.

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DESIGN FEATURES - RX-4200 MODULE SET FOR DOMSAT VIDEO RECEPTION

Optimized specifically for TV reception from C-band Domestic Communications Satellites (DOMSATs), these six microwave circuit modules provide the advanced experimenter or equipment manufacturer with all RF circuitry necessary to assemble a fully tunable, 3.7 to 4.2 GHz dual-conversion superheterodyne receiver.

- Dual Conversion - 1.2 GHz first IF with low-side injection minimizes images. 70 MHz second IF simplifies baseband processing.

- Continuous Tuning - First Local Oscillator is voltage tuned and may be AFC'd. High-stability crystal-controlled Second Local Oscillator.

- Modular Construction - See block diagram on reverse.
  MX-4200 Double-balanced First Mixer exhibits 8 dB conversion loss.
  LO-3000 First Local Oscillator is voltage tuned from 2.5 to 3 GHz.
  RF-1200 Ampli-Filters (2 supplied) each provide 15 dB gain, 2 dB noise figure, 100 MHz maximum bandwidth at 1.2 GHz.
  LO-1270 Second Local Oscillator offers 40 dB spurious rejection.
  MA-1200 Second Double-balanced Mixer includes 30 dB of 70 MHz Second IF Amplification; filtering for 40 MHz bandwidth.

- Ease of Application - the modules downconvert C band to 70 MHz with 40 dB of conversion gain. The user merely adds a power supply and jumper cables, antenna, low-noise preamplifier and baseband processing circuitry to develop a complete DOMSAT TV Receive-Only terminal.

- Straightforward Interface - All units operate from a single +13.5 VDC supply, at approx. 250 mA total. Modules are equipped with type SMA Female precision microwave connectors for easy interconnection with user-supplied coaxial jumper cables. Microstripline circuitry and ion-implanted microwave bipolar transistors assure high reliability.

- Low Cost - The six circuit assemblies comprising the RX-4200 Module Set are supplied for $1000 complete. Orders must be prepaid in US funds. For a complete, packaged receiver (including RF Modules, Baseband Processor, Power Supply and Tuner) order the Model TV-4200 Satellite Video Receiver, at $1995.00 plus applicable shipping charges.

- Fully Warranted - If operated in accordance with the instructions provided, we warrant all circuit modules to perform to their published specifications for a period of 90 days, unless abused physically or electrically. We can of course not guarantee performance of your TVRO terminal, but if you properly interface these modules to a suitable antenna, LNA, and baseband unit, you should be enjoying satellite TV in short order.

All prices and specifications subject to change without notice.

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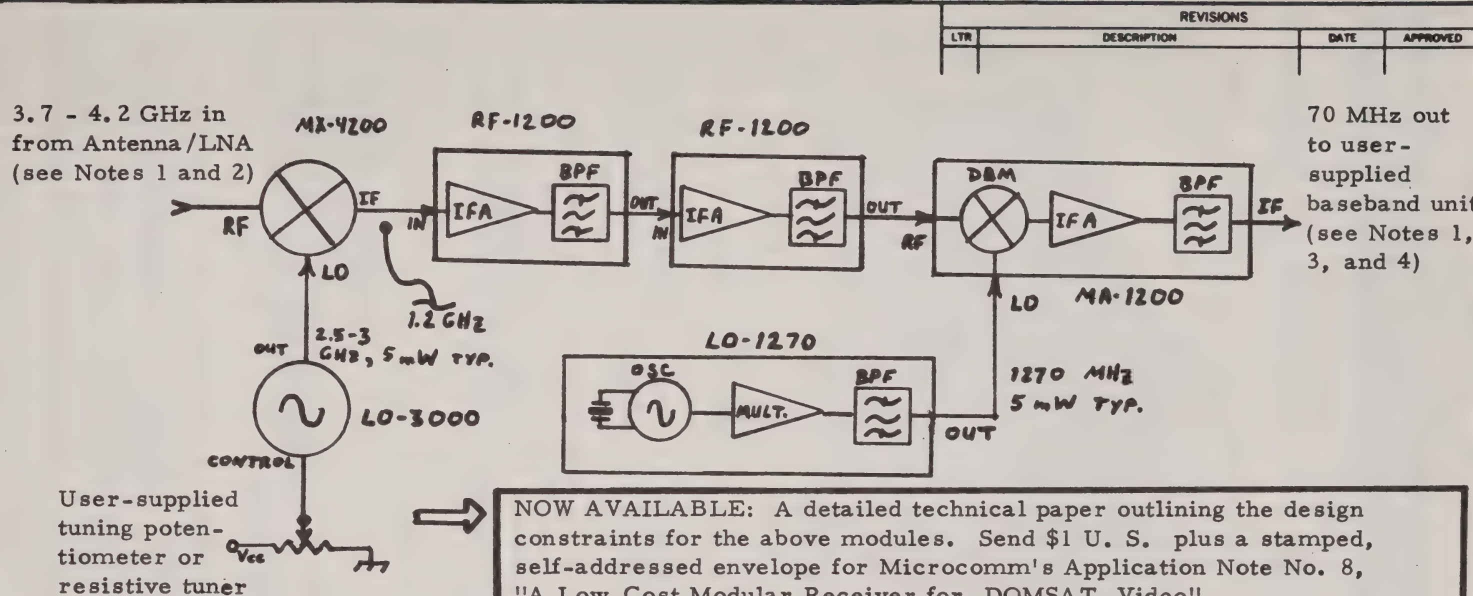

NOW AVAILABLE: A detailed technical paper outlining the design constraints for the above modules. Send $1 U. S. plus a stamped, self-addressed envelope for Microcomm's Application Note No. 8, "A Low-Cost Modular Receiver for DOMSAT Video".

NOTES:

1. Video format and modulation characteristics are included in Microcomm's Application Note #3, "A Vidiot's Guide to Microwave TV Links". Reprints are available for $1 US plus a stamped, self addressed envelope.

2. For LNA/Antenna selection criteria and recommendations, see Microcomm's Application Note #4, "Antenna/LNA Tradeoff Analysis for C-band Video Terminals". Send $1 US plus a stamped, self addressed envelope.

3. Baseband Unit typically includes a limiter/discriminator or PLL Demodulator, video amplifiers, CCIR de-emphasis circuit, audio subcarrier demodulator and amplifier, sync tip clamp, buffers, and RF modulator.

4. Construction details on a fully compatible baseband unit, along with full schematics on the downconversion modules, may be found in the RX-4200 User's Manual, available from Microcomm for $25 US funds.

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BLOCK DIAGRAM - RX-4200
Modular DOMSAT Video Rcvr

SIZE	CODE IDENT NO.	DRAWING NO.
		RX-4200-301C
SCALE		SHEET 1 OF 1

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SHIPPING DAMAGE CLAIMS

Prior to unpacking the RX-4200 Module Set, all shipping containers should be carefully examined for any evidence of mechanical or physical damage. Any indication of mis-handling or other damage should be reported at once, to both the carrier delivering the parcel and to Microcomm.

After unpacking the modules, visually inspect external parts for damage to the cases, PC boards, connectors, power feedthru terminals, etc. The shipping containers and packing material should be saved in case it is necessary to reship any modules.

If any modules have been damaged in transit, notify both the carrier and Microcomm at once. Retain shipping cartons and packing material for carrier's inspection. Microcomm will immediately arrange for either replacement or repair of your damaged modules without waiting for damage claim settlements.

WARRANTY INFORMATION

Microcomm's warranty against defects in materials or workmanship extends for a period of 90 days from the date of shipment, to the original purchaser only. If a TVRO system utilizing the RX-4200 Module Set should fail within the warranty period, it is the responsibility of the user to verify that the system failure is due to a module malfunction. The spectral analysis troubleshooting technique outlined in Section 2 of this Manual is highly recommended, in that it permits a system failure to be isolated to a single module. Another fault isolation technique which aids in identifying a failed module is to compare the quiescent current drawn by each module from the system power supply against reference values established when the system was in good operating condition, or against the nominal values indicated in Sections 3 through 7 of this Manual. Since most failure modes will result in a change in DC conditions, an improper current level is a good indication of a failed module.

Upon verifying a failure and isolating it to a single module, contact the Microcomm factory for a return authorization prior to shipping the failed module for warranty repair. If, in the sole opinion of Microcomm, the failure is attributable to any cause other than negligence on the part of the user, mis-use, or mis-handling, the unit will either be repaired at no charge, or a replacement module shipped.

Should a failure occur after expiration of the warranty, Microcomm will perform repairs on a time-and-materials basis, or if it appears that repair costs will exceed replacement costs, a replacement module will be shipped COD. Should the user fail to isolate a failure to the module level, or if a properly operating module is returned for testing, all testing and trouble-shooting time will be billed at the prevailing laboratory service rate, regardless of the warranty status of the module or modules involved.

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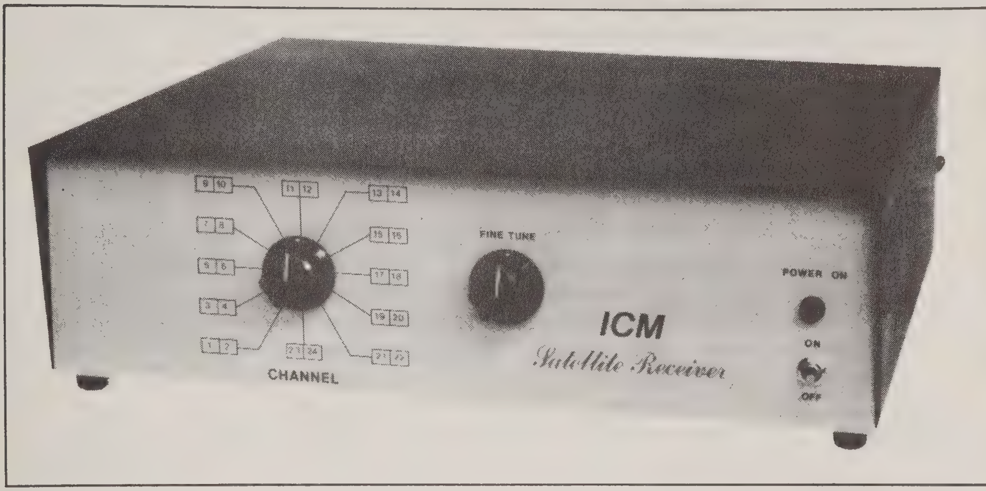
TV·4200 *Satellite Receiver*



Fully Tunable
COVERS ALL SATELLITE CHANNELS 3.7-4.2GHZ BAND.

Dual Audio Outputs
6.2 AND 6.8MHZ AUDIO STANDARD, OTHERS AVAILABLE.

Easy To Use
SIMPLE TUNING
BUILT IN LNA POWER SUPPLY
OUTPUT LEVELS COMPATIBLE WITH VIDEO MONITOR
OR VTR INPUT.

ECONOMICALLY PRICED at $1995.00 U. S. Delivery stock to 6 wks.
Plus Shipping Charges : $10.00 within US; $25.00 in Canada
Please add applicable state or province sales taxes.
All orders must be prepaid by U. S. Dollar Cashier's Check or Money Order.

All prices and specifications subject to change without notice.

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SECTION 2

MODULE INTERFACING

INTRODUCTION

This Section details the RF and DC interface requirements for the RX-4200 Module Set. Sources for the required coaxial cable and microwave connectors are listed, and a strategy for testing the receiver during system integration is proposed.

DC REQUIREMENTS

All of the active circuits comprising the RX-4200 Module Set operate from a supply potential of +13.5 VDC, as does the recommended baseband processor board detailed in Section 8 of this Manual. This potential was selected as being midway between 12 and 15 VDC, the range of acceptable operating potentials for a variety of standard microwave circuit modules. In addition, +13.5 VDC represents the potential of a fully charged lead-acid storage battery, suggesting that battery operation for the video receiver is practical in those applications requiring it.

Because the receiver employs a voltage-controlled First Local Oscillator, it is essential to utilize a power supply exhibiting minimal ripple and the best available load and line regulation, in order to maximize the stability of the receiver. The RX-4200 Modules collectively require on the order of 250 mA from the power supply, with the baseband processor detailed in Section 8 of this Manual requiring an additional 200 mA. In order to accommodate the power requirements of the antenna-mounted Low-Noise Amplifier (LNA), it is recommended that a 1 Ampere power supply be employed. Commercial open-frame power supplies are available from a number of suppliers in the $40 price class. Vendors to consider include the following:

ACDC Electronics	Power-One, Inc.
Abbott Transistor Labs	Power Systems Inc.
Acopian Corp.	Power/Mate Corp.
Alpha Power Inc.	Powertec, Inc.
Electrostatics Inc.	Reacor Inc.
ELPAC Electronics, Inc.	Sorensen Company
ERA Transpac Corp.	Standard Power, Inc.
Faratron Corp.	Technipower, Inc.
Hope Electronics	Tele-Dynamics
Kepco Inc.	

Users preferring to construct their own power supply should consider employing an adjustable-output three-terminal voltage regulator IC such as the National Semiconductor LM317, so that the supply potential can be readily adjusted to the optimum +13.5 VDC.

In order to minimize thermal drift, it is desirable to place the power supply well away from the two Local Oscillator modules (LO-3000 and LO-1270), and to provide ample heat-sinking to the outside of any cabinet used, for all heat-generating components.

All active circuits receive operating potential through feedthru capacitors protruding through the groundplane side of the printed circuit board or, in the case of the LO-3000 VCO, threaded into the side of the housing. Since the feedthru capacitors employed provide adequate RF decoupling, it is permissible to loop the power supply wiring directly between modules, utilizing AWG 18 or larger insulated hookup wire. If the receiver is to be operated in an environment of high electrical noise, shielded cable may be employed for power wiring. Grounding of the modules through the mounting screws which will secure their enclosures to the receiver chassis or cabinet will prove acceptable, as will routing the ground return through the outer conductors of the coaxial cables which will interconnect the signal ports of the various modules.

CAUTION: DO NOT UNDER ANY CIRCUMSTANCES APPLY NEGATIVE POWER SUPPLY POTENTIAL TO THE FEEDTHRU CAPACITORS OF ANY CIRCUIT MODULE! ASSURE THAT APPLIED POTENTIAL IN NO EVENT EXCEEDS +15 VDC! AND NEVER APPLY POWER SUPPLY POTENTIAL TO THE RF (SIGNAL) CONNECTOR OF ANY MODULE!

RF INTERCONNECT

The various signal ports of all the RX-4200 Modules are equipped with a precision female microwave connector known variously as type SMA (for Subminiature, Type A) or type OSM (for Omni-Spectra Microwave, a trade designation of the company originally producing this connector). Do not attempt to attach to these recepticals any connector type other than SMA-Compatible male plugs, lest the modules be irreparably damaged.

The various signal ports are interconnected according to the block diagram shown in Section 1 of this Manual, utilizing short (5 inch typ.) coaxial jumper cables equipped with type SMA plugs. The best coaxial cable to utilize for the jumper cables is type RG-142B/U, a miniature (0.2" OD) coax similar in appearance to the familiar Type RG-58, but with significant differences in construction and operating characteristics. RG-142B/U employs a TFE dielectric (rather than the polyethelene dielectrics used in less costly cables), has a solid, silver plated center conductor and dual silver plated braided shields, and offers low loss and constant VSWR well

into the GHz spectrum. Although this cable is costly (up to $2 per foot in small quantities), the use of lesser cables is a false economy, in that doing so can seriously degrade the performance of the RX-4200 Module Set. RG-142B/U cable is manufactured by several companies, including Alpha Wire, Belden Corp., and Times Wire and Cable Co. It is available from numerous electronics parts distributors across the U. S., although many distributors are reluctant to sell in small quantities.

One SMA plug recommended as being easy to install on type RG-142B/U cable is the 142-0261-001 from E. F. Johnson Company, Waseca MN 56093. This plug sells for under $5 in single quantities, and installs without any specialized tools. One difficulty occasionally encountered with this connector is that the hole in the center pin sometimes will not clear the plated center conductor of the cable. If this occurs, it is a simple matter to drill out the hole in the center pin with a Number 58 high-speed steel twist drill, prior to mounting the connector.

For those module users who prefer not to assemble their own jumper cables, Microcomm will supply assembled jumpers, consisting of 5 inches of RG-142B/U with the E. F. Johnson SMA plugs installed at both ends, for $12.00 U. S. each, FOB San Jose CA. Please allow six weeks for delivery.

When mating SMA plugs to their recepticals, care should be taken to apply proper torque, which for the connectors recommended is 6 to 8 inch-pounds. Insufficient torque will result in an intermittent RF connection, while excessive torque can readily damage the connectors. If no torque wrench is available, an acceptable procedure is to install the connectors finger-tight, and then give a slight pull with a small open-end wrench. The connector's coupling nut should rotate not more than 45 degrees during the final tightening operation.

ANCILLARY CIRCUITRY

After completing the RF and DC interconnect as outlined above, the RX-4200 Module Set must be interfaced to a tuning control and baseband processing circuitry, both user-supplied, before DOMSAT video reception can be attempted. Fortunately, neither the tuner nor the baseband circuits are particularly exotic, nor do they require extensive test equipment; thus, they are considered tasks ideally suited to the electronics experimenter of average ability.

Tuner circuit options are detailed in Section 4 of this Manual. Complete construction details for a baseband processor are included in Section 8.

SYSTEM TESTING

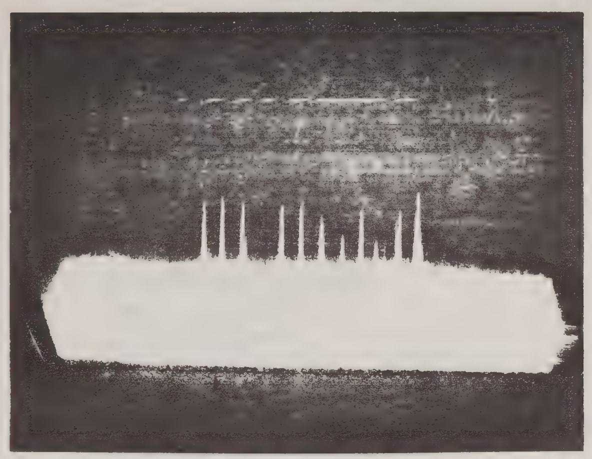
By far the most useful single test instrument in optimizing performance of a TVRO earthstation is the microwave spectrum analyzer, and users of the RX-4200 modules are strongly urged to rent or borrow such an instrument during final system integration. Often a suitable instrument can be obtained on loan from a local cable TV company, UHF TV station, or college or university Electronics department. It is also possible to assemble a workable spectrum analyzer from surplus components, and an article has been published by Microcomm's Chief Engineer illustrating one such design. For a reprint of "A Low Cost Microwave Spectrum Analyzer" by H. Paul Shuch, send $1.00 U. S. plus a stamped, self-addressed envelope to Microcomm, and request Application Note #9.

The use of a spectrum analyzer in viewing the downlink spectra of several DOMSATs is illustrated in Figure RX-4200-901 on the following page. With the Low-Noise Preamplifier mounted at the antenna, it is possible to view the entire 3.7 to 4.2 GHz band directly on a spectrum analyzer. This facilitates antenna aiming and feed positioning (adjustments are made for the maximum signal amplitude displayed on the analyzer), as well as rough carrier-to-noise measurements, depending upon the IF bandwidth of the spectrum analyzer used. Note that each satellite viewed has its own distinct "spectral signature", and that spectrum analysis is a great aid in identifying the various satellites within sight of a given location.

By applying the amplified satellite downlink passband to first-conversion modules MX-4200, LO-3000 and one or both RF-1200 stages, it is possible to view the downconverted passband on a spectrum analyzer, as indicated in Figure RX-4200-902. This test verifies the proper operation of the first downconversion modules, the tuner, and establishes an indication of first IF bandwidth, as the photographs indicate.

If the second conversion modules (MA-1200 and LO-1270) are now included in the system, the 70 MHz IF can be viewed on the spectrum analyzer, as indicated in Figure RX-4200-904. Note that the spectrum display gives a clear indication of the degree of adjacent transponder rejection, which is a function of the second IF bandwidth. It is also possible to expand the horizontal display, so as to view in detail the FM video sidebands, energy dispersal waveform, and modulated audio subcarriers, as indicated in Figure RX-4200-903.

Detailed spectrum analysis at various points throughout the signal path establishes baseline data for future system troubleshooting. It also provides the microwave experimenter with an ideal way to familiarize himself with the operation and signal characteristics of a DOMSAT video system.



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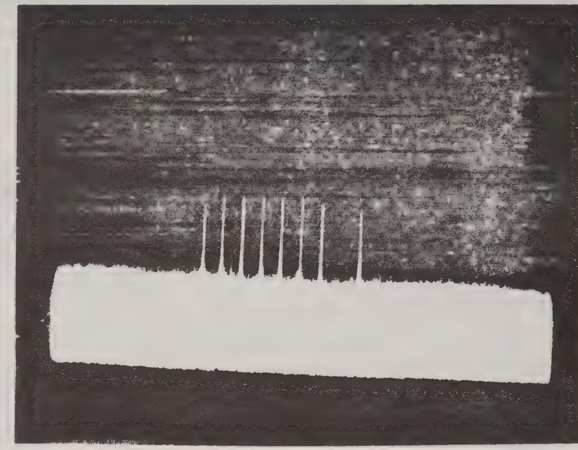
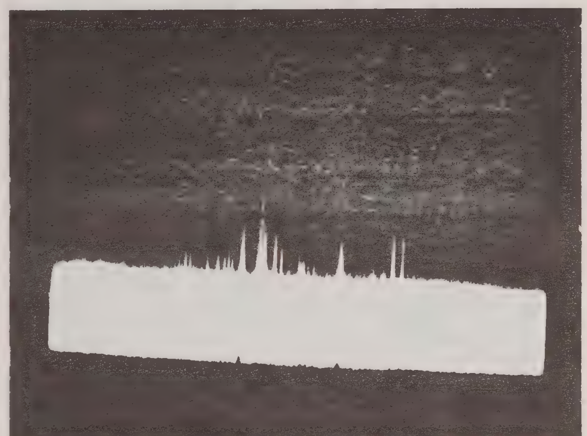


COMSTAR A

WESTAR II



TEST CONDITIONS:

Antenna: Kintech 4.7 meter Solid Reflector, 0.47 F/D
Feed: Prime Focus Rectangular Waveguide Horn
LNA: Dexcel DXA-3091-01, 150° K, 30 dB Gain
Spectrum Analyzer: Hewlett-Packard 8551B
F_c: 4 GHz   Resolution: 100 KHz
Horiz: 100 MHz/cm   Vert: 10 dB/cm

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APPROVALS	DATE
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DOMSAT Spectral Signatures

SIZE	CODE IDENT NO.	DRAWING NO.
		RX-4200-901
SCALE		SHEET 1 OF 1

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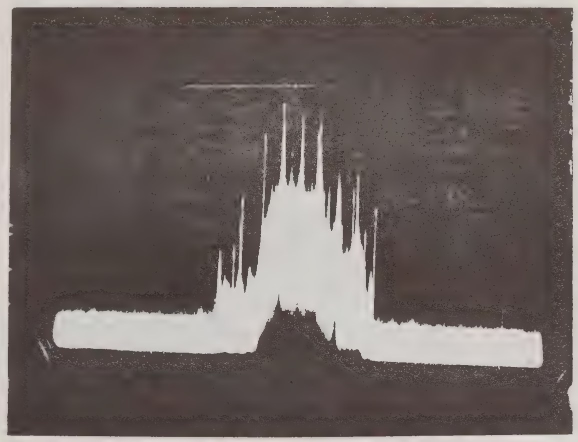
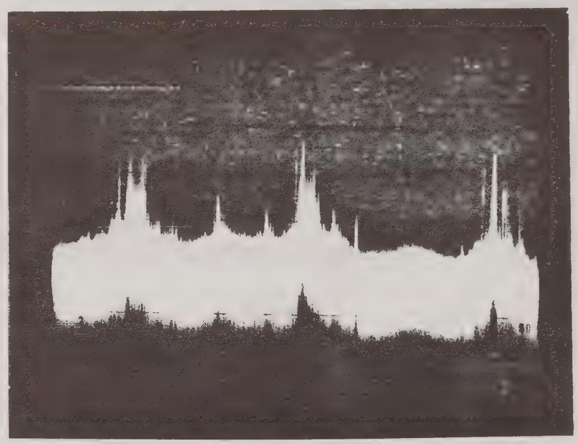


Horiz: 100 MHz/cm



Horiz: 10 MHz/cm

TEST CONDITIONS
Satellite: RCA Satcom F1
Antenna, LNA, Feed: per RX-4200-901
Downconverter Modules : Microcomm RX-4200 (through 1st IF only)
Spectrum Analyzer: Hewlett-Packard 8551B
F_c: 1.2 GHz
Vert: 10 dB/cm
Resolution: 100 kHz

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APPROVALS	DATE

DOMSAT 1st IF
Selectivity Characteristics

SIZE	CODE IDENT NO.	DRAWING NO.
		RX-4200-902
SCALE		SHEET 1 OF 1

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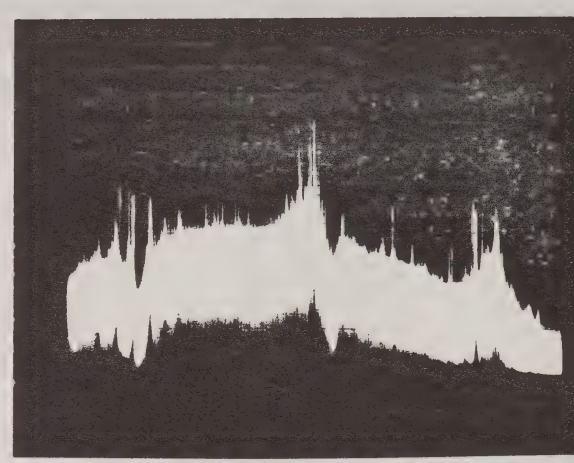
LTR	DESCRIPTION	DATE	APPROVED



3 Adjacent Video Channels
viewed after downconversion
to 70 MHz.

TEST CONDITIONS:
per RX-4200-903, except
Horizontal Scale = 10 MHz/cm

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APPROVALS	DATE
SL	5-79

DOMSAT Adjacent Channel Rejection Characteristics

SIZE	CODE IDENT NO.	DRAWING NO.
		RX-4200-904
SCALE		SHEET 1 OF 1

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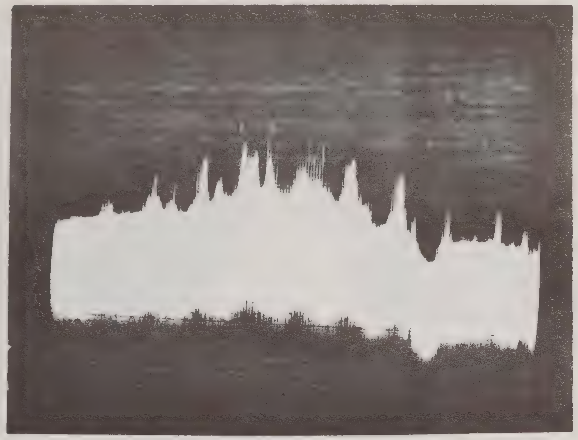
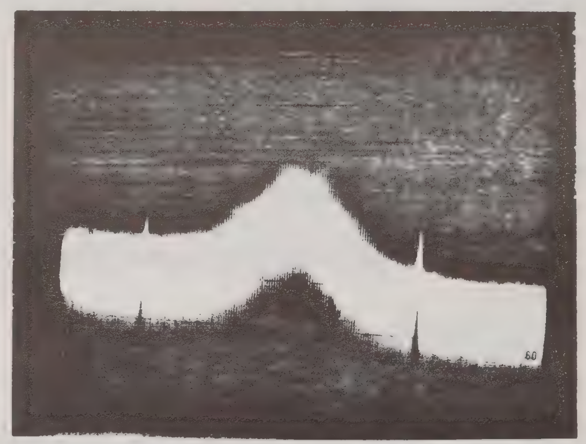


Modulated Video Transponder



Dithered Video Transponder

TEST CONDITIONS

Satellite: RCA Satcom F1
Antenna, LNA, Feed: Per RX-4200-901
Downconverter Modules: Microcomm RX-4200-901
Spectrum Analyzer: Hewlett-Packard 8551B
F_c : 70 MHz
Horiz: 3 MHz/cm
Vert: 10 dB/cm
Resolution: 100 kHz

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APPROVALS	DATE
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DOMSAT Video Spectra

SIZE	CODE IDENT NO.	DRAWING NO.
		RX-4200-903
SCALE		SHEET 1 OF 1

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SECTION 3

DOUBLE-BALANCED MIXER MX-4200

INTRODUCTION

Heterodyne downconversion of the satellite downlink passband to a first IF of 1.2 GHz occurs in the MX-4200 Double-Balanced Mixer Module. This is a passive mixer exhibiting nominally 7 dB of conversion loss and 20 dB of isolation between ports, when driven with 5 mW (+7 dBm) of injection from the LO-3000 Oscillator Module described in Section 4 of this Manual. Since the MX-4200 is a passive device, it requires no power supply connection.

CIRCUIT DESCRIPTION

The MX-4200 performs heterodyne conversion in a balanced ring of four matched Schottky-barrier diodes, coupled with wideband transmission line transformers, as indicated in the Schematic in Data Sheet MX-4200-101 on the following page. The Data Sheet also includes packaging dimensions and typical performance curves. RF, LO and IF connections are all via Type SMA female coaxial recepticals.

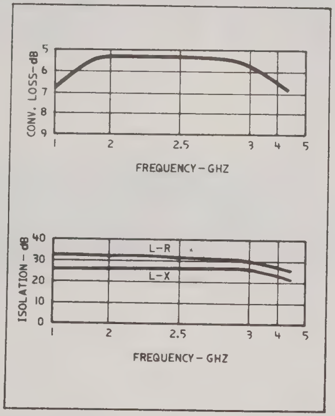
Since the MX-4200 module is hermetically sealed and deemed non-repairable, no construction details are included in this Manual. Fortunately the mixer contains no active devices and, being a passive circuit, exhibits extremely high reliability. Short of mechanical abuse, there are virtually no conditions under which this mixer can be expected to fail in DOMSAT TVRO service.

Should it ever be necessary to verify the proper performance of this Mixer, its conversion loss can be readily measured on a spectrum analyzer, by connecting LO injection from the LO-3000 Oscillator Module, and an RF signal at -20 dBm or below from a signal generator operating in the 4 GHz region. By tuning both the signal generator and the LO-3000 to maintain a 1.2 GHz separation, it is possible to measure the IF output across the mixer's operating band.

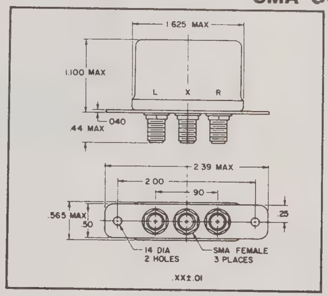
REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

MICROWAVE DOUBLY BALANCED MIXER

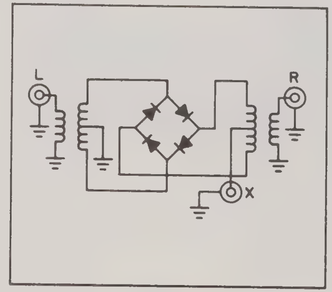
- 1.7-4.2 GHz
- 7dB TYPICAL CONVERSION LOSS
- SMA CONNECTOR PACKAGE



TYPICAL PERFORMANCE



PACKAGE



SCHEMATIC

PRELIMINARY

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DOUBLE-BALANCED MIXER SPECIFICATIONS

SIZE	CODE IDENT NO.	DRAWING NO.
		MX-4200-101
SCALE		SHEET 1 OF 1

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SECTION 4

VOLTAGE CONTROLLED OSCILLATOR

LO-3000

INTRODUCTION

The key to the frequency agility of DOMSAT video receivers utilizing the RX-4200 Module Set is the use of a Voltage Controlled Oscillator (VCO) for heterodyne downconversion of any desired satellite transponder downlink frequency to the first IF. The VCO provides typically 5 mW (+7 dBm) of Local Oscillator injection to the first balanced mixer module, via a type SMA Female output connector. LO Frequency is voltage tunable from 2.5 to 3 GHz with a control potential of typically 2 to 10 VDC. Tuning voltage can be derived from a single potentiometer, resistive detent tuner or user-supplied Automatic Frequency Control (AFC) circuit, as described elsewhere in this Section. The VCO Module is fully shielded by its nickel-plated aluminum enclosure, and draws approximately 50 mA from the 13.5 VDC power source common to all modules in the RX-4200 set.

CIRCUIT DESCRIPTION

The LO-3000 Voltage Controlled Oscillator is shown schematically in Figure LO-3000-401, with parts list appearing on the page following.

The key to the operation of the VCO Module is microcircuit U1, a complete varactor-tuned common-base bipolar fundamental oscillator circuit in a TO-8 package. The Varactor-Tuned Oscillator (VTO) hybrid utilizes thin-film technology, with gold traces and chip semiconductors on precision high dielectric constant substrates for high reliability.

The VTO hybrid is mounted on a microstrip circuit board, which connects the output terminal to the SMA receptical (J1) via a 50 ohm transmission line. Resistor R1 and feedthru capacitor C1 afford RF decoupling for the tuning potential, feedthru capacitor C2 decouples the V_{CC} line, and diode D1 provides reverse polarity protection for U1.

Most stable oscillator operation results when the the tuning voltage terminal (C1) is driven by a low-impedance source. Thus it is recommended that the user provide an external capacitive bypass (typically 1000 uf, 15 VWDC electrolytic) from C1 to ground. This bypass capacitor is normally located in the tuner circuitry.

Figure LO-3000-901 shows a typical tuning potential vs. LO Frequency curve for the VCO module. Also shown are DOMSAT channels which result as tuning potential is varied, assuming a 1200 MHz First IF.

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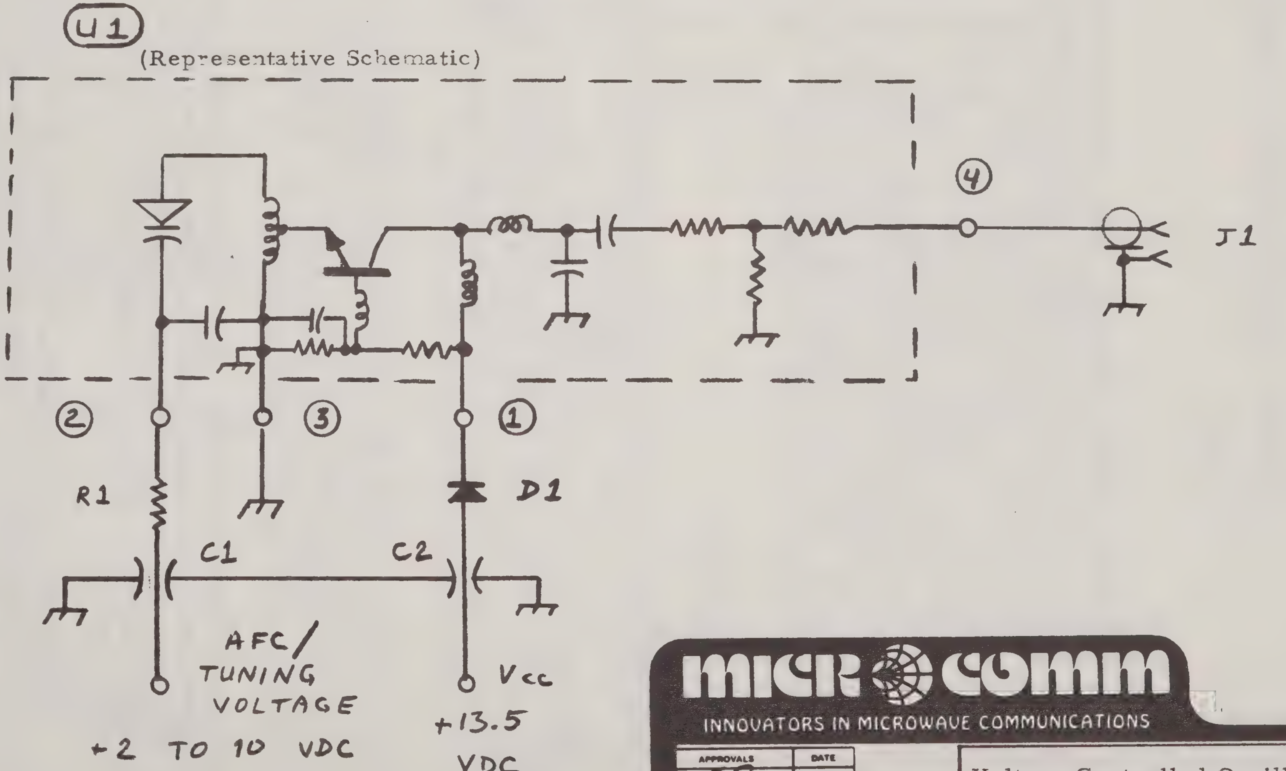

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Voltage Controlled Oscillator
SCHEMATIC DIAGRAM

SIZE	CODE IDENT NO.	DRAWING NO.
		LO-3000-401
SCALE		SHEET 1 OF 1

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LTR	DESCRIPTION	DATE	APPROVED

Designation	Description
C1, 2	Filter Feed-thru, 5000 pf, 8-32 thread, Modpak P-000. (One piece supplied with Enclosure)
D1	General Purpose Silicon Diode, 1N914 or equiv.
J1	Type SMA Female end-launch connector, Modpak H-034. (Supplied with Enclosure)
R1	Carbon Composition Resistor, 10 ohm 1/4 watt, 10%.
U1	VCO Microcircuit, Avantek VTO-8240 or Watkins Johnson V802.
Enclosure	Modpak 7123-4. Drill and tap 8-32 hole in side opposite C1 mounting hole.
Circuit Board	Microcomm LO-3000-601

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Voltage Controlled Oscillator
PARTS LIST

SIZE	CODE IDENT NO.	DRAWING NO.
		LO-3000-501
SCALE		SHEET 1 OF 1

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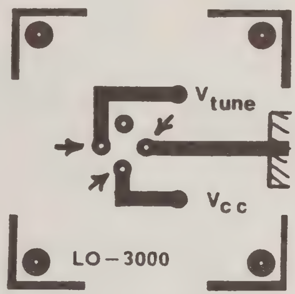
REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



- #27, 4 plcs.
- #65, 4 plcs.
- Counter-sink groundplane metallization with 1/8" twist drill, 3 plcs.
- Notch Circuit Board with file or nibbler tool, 0.1" x 0.6".

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Voltage Controlled Oscillator
DRILLING INSTRUCTIONS

SIZE	CODE IDENT NO.	DRAWING NO. LO-3000-701
SCALE		SHEET 1 OF 1

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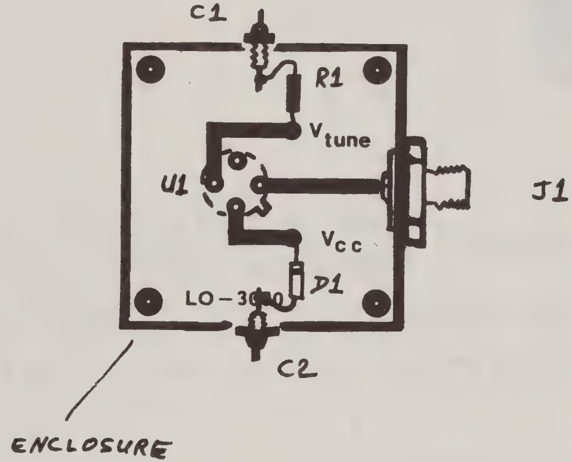
LTR	DESCRIPTION	DATE	APPROVED



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Voltage Controlled Oscillator
ASSEMBLY DRAWING

SIZE	CODE IDENT NO.	DRAWING NO.
		LO-3000-801
SCALE		SHEET 1 OF 1

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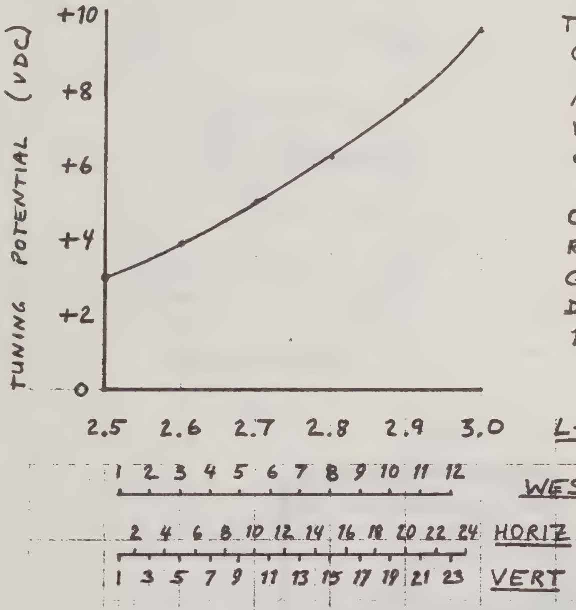

TYPICAL TUNING CHARACTERISTICS -

MODEL LO-3000 VOLTAGE TUNED OSCILLATOR

CHANNEL ASSIGNMENTS REFER TO 3.7 - 4.2 GHZ DOMSAT BAND DOWNCONVERTED TO 1.2 GHZ 1ST I-F.

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APPROVALS	DATE
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Voltage Controlled Oscillator
TYPICAL TUNING CURVE

SIZE	CODE IDENT NO.	DRAWING NO.
		LO-3000-901
SCALE		SHEET 1 OF 1

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TUNER CONSIDERATIONS

Users of the RX-4200 Module Set have developed a number of techniques for generating the required range of tuning voltages to cover the 24 assigned DOMSAT transponder frequencies. Perhaps the simplest approach is to use a potentiometer as a resistive voltage divider. A 1 K ohm potentiometer is connected from V_{cc} to ground, with the wiper contact connected to the tuning voltage terminal (LO-3000 C1). Don't forget to install the 1000 uf bypass capacitor, as discussed previously. If a ten-turn potentiometer with a counter dial is employed, it will be possible to develop a calibration chart, permitting rapid channel selection by merely dialing in a predetermined counter setting.

Note that the use of a 1 K ohm potentiometer across a 13.5 VDC supply results in 180 mW of power being dissipated in the potentiometer. In order to avoid frequency drift due to excessive potentiometer heating, be sure to use a potentiometer rated at one-half watt or greater dissipation. It is also possible to use a tuning potentiometer of higher value (10 K ohms or greater), but the higher impedance presented to the VCO tuning terminal may result in oscillator instability. An alternative is to drive the wiper contact of a 10 K ohm potentiometer into an emitter follower designed for a lower output impedance.

The most popular tuner arrangement for DOMSAT video receivers is the detent tuner shown schematically in Figure LO-3000-402. Here a 12-position rotary switch selects an output from a resistive voltage divider. A ganged potentiometer (R16) allows symmetrical fine tuning to allow selection of horizontal, vertical, or half-transponder channels, and an emitter follower (Q1, R15 and C1) assures a low drive impedance to the VCO. Trimmer potentiometers R1 and R2 allow calibration of the high and low ends of the band respectively, and tuning linearity is such that with the band edges calibrated, adequate fine-tuning range exists to allow each transponder to be tuned at its allotted switch position.

OSCILLATOR STABILITY

It should be remembered that a voltage-controlled oscillator is tuned in frequency by varying one or more operating potentials. Thus any variation in supply potentials to the V_{cc} or tuning potential terminals which result from hum, ripple, or poor supply regulation will cause frequency modulation of the VCO. Care should be taken to assure that the power supply used in conjunction with the RX-4200 Module Set be well regulated and filtered.

The VCO is also prone to frequency-pulling when its output RF connector is terminated in a reactive mismatch. If the VCO will not tune smoothly across the 2.5 to 3 GHz band when connected to the MX-4200 Mixer, it may be advisable to reverse the RF and LO ports of the mixer, the RF port sometimes providing a better impedance match. A 3 dB resistive attenuator or ferrite isolator may also be installed between the VCO output and the mixer's LO port.

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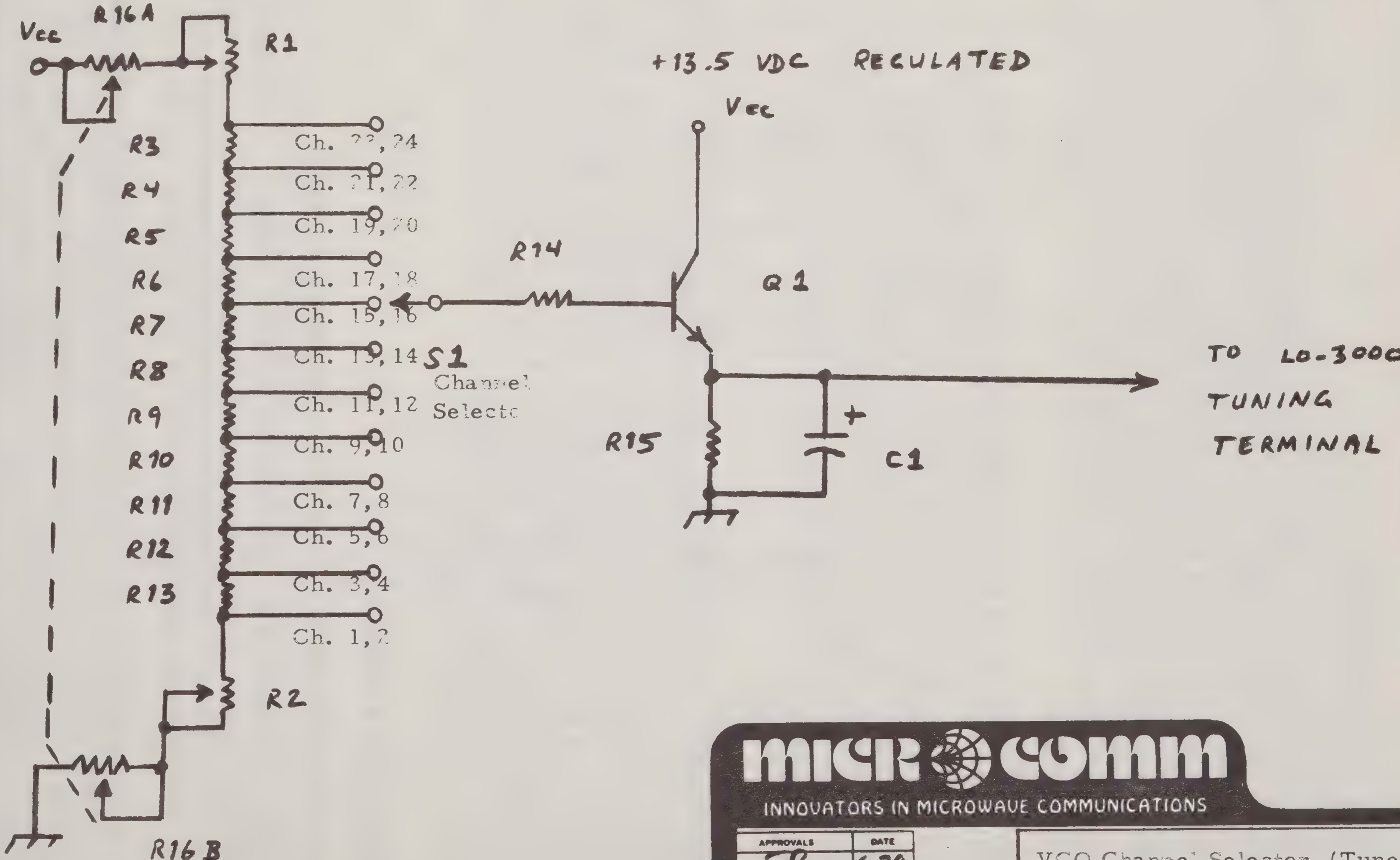

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VCO Channel Selector (Tuner)
SCHEMATIC DIAGRAM

SIZE	CODE IDENT NO.	DRAWING NO.
		LO-3000-402
SCALE		SHEET 1 OF 1

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REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

Designation	Description
Q1	General Purpose NPN Silicon Transistor (2N2222 or equiv.)
C1	Electrolytic Capacitor, 1000 uf, 15 WVDC
R1, 2	10-turn trim potentiometer, 10K ohm
R3 - 14	Carbon Composition Resistor, 1 K ohm 1/4 watt, 5%
R15	Carbon Composition Resistor, 470 ohm 1/4 watt, 10%
R16	Dual Ganged Potentiometer, 2 K ohm/section, linear taper
S1	12 position rotary switch, shorting

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VCO Channel Selector (Tuner)
PARTS LIST

SIZE	CODE IDENT NO.	DRAWING NO.
		LO-3000-502
SCALE		SHEET 1 OF 1

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AUTOMATIC FREQUENCY CONTROL

The LO-3000 Voltage Controlled Oscillator is compatible with a number of AFC schemes, although the inherent high stability of this oscillator, in combination with the relatively wide satellite transponder bandwidth, seem to make AFC unnecessary except in the most demanding applications. In general terms, AFC is accomplished by sampling the DC component at the output of the discriminator or phase-locked loop used for FM video demodulation in the Baseband Processor. This DC level will be at ground potential when the received signal is centered in the receiver's passband, increasing in a positive or negative direction as the signal drifts high or low in frequency. The varying DC level is applied to one of the inputs of a differential amplifier, the other input being driven by a voltage divider used for channel selection, as shown in the Tuner schematic Figure LO-3000-402. The output of the differential amplifier thus tracks changes in the demodulator's DC output level, developing a corrected tuning potential at its output which, if the gain of the differential amplifier is properly adjusted, will keep the LO frequency aligned so as to always center the selected channel in the receiver's passband.

Although Microcomm does not manufacture an AFC board for the RX-4200 module set, several published AFC schemes appear compatible with these modules, with perhaps minor modification. The interested user is referred to the following sources of AFC information:

1) "The Howard Terminal", available from TVRO Plans, PO Box G, Arcadia OK 73007. Contains complete schematics on an AFC circuit which, though complex, is completely compatible with both the LO-3000 Oscillator and the baseband processor described in Section 8 of this User's Manual. Chief drawback of the Howard AFC circuit is that it requires both positive and negative power supply potentials.

2) "VHF/UHF Manual" by D. S. Evans and G. R. Jessop, published by the Radio Society of Great Britain. Recent editions of the RSGB manual contain AFC circuits for use with reflex Klystrons and Gunn oscillators in the amateur 3 cm band. These circuits can be adapted for use with the LO-3000 VCO, typically by varying the gain and DC offset voltage of the operational amplifier microcircuits used.

3) Microwave Associates, South Avenue, Burlington MA 01803, has compiled a collection of applications circuits for their "Gunnplexer" 10 GHz transceiver units. These notes contain several AFC circuits which can be made compatible with the RX-4200 Module Set with little difficulty. Request the Gunnplexer information packet.

SECTION 5

AMPLI - FILTER RF-1200

INTRODUCTION

Two identical 1.2 GHz Ampli-Filter Modules are utilized in the Microcomm RX-4200 Module Set to establish the required First IF Gain, Dynamic Range, Noise Figure and Selectivity. Each Ampli-Filter consists of a single-stage bipolar low-noise IF amplifier exhibiting 15 dB of gain and 2 dB noise figure, followed by a two-pole bandpass filter exhibiting a one-dB bandwidth of 50 MHz. Microstripline construction and ion-implanted microwave transistors are employed. The large active area transistor chip selected allows high quiescent collector bias, maximizing IF dynamic range. Each ampli-filter is equipped with Type SMA input and output coaxial recepticals, is fully shielded by the enameled, die-cast aluminum enclosure utilized, and draws approximately 20 mA from the 13.5 VDC power source common to all receive modules.

CIRCUIT DESCRIPTION

The RF-1200 Ampli-Filter is shown schematically in Figure RF-1200-401, with parts list appearing on the page following.

Transistor Q1 forms a common-emitter Class-A low noise amplifier centered on 1200 MHz. Its input circuit, consisting of microstripline inductor L1 and microstripline capacitor C7, serves to transform the transistor's input complex impedance to a termination representing Γ_0, the source reflection coefficient for optimum noise figure. Chip capacitor C1 serves merely as a DC block for the input signal applied at J1.

The output matching circuit, consisting of microstrip transmission lines L2 and L3, and DC Blocking Capacitor C2, terminates the output of Q1 in its complex conjugate. Microstripline inductors L4 and L5 are resonated by piston trimmer capacitors C3 and C4, forming a 2-pole bandpass filter which establishes the overall selectivity of the ampli-filter module. The amplified, filtered IF signal appears at output connector J2 at a nominal 50 +j 0 ohm impedance.

Zener diode D1 serves to clamp the collector-to-emitter potential of Q1 near 10 volts. It is a 9.1 volt zener reverse-biased past its knee by R1, at the same time forward-biasing the emitter-to-base junction of Q1. Noise spikes generated by the zener diode are bypassed to ground by C9 and C10, and R2 is a parasitic suppression resistor used to prevent low-frequency oscillations. Base bias is applied to the active device via microstrip transmission line RFC1, which is bypassed by resonant transmission line C5. Microstrip capacitor C8 provides additional bias decoupling.

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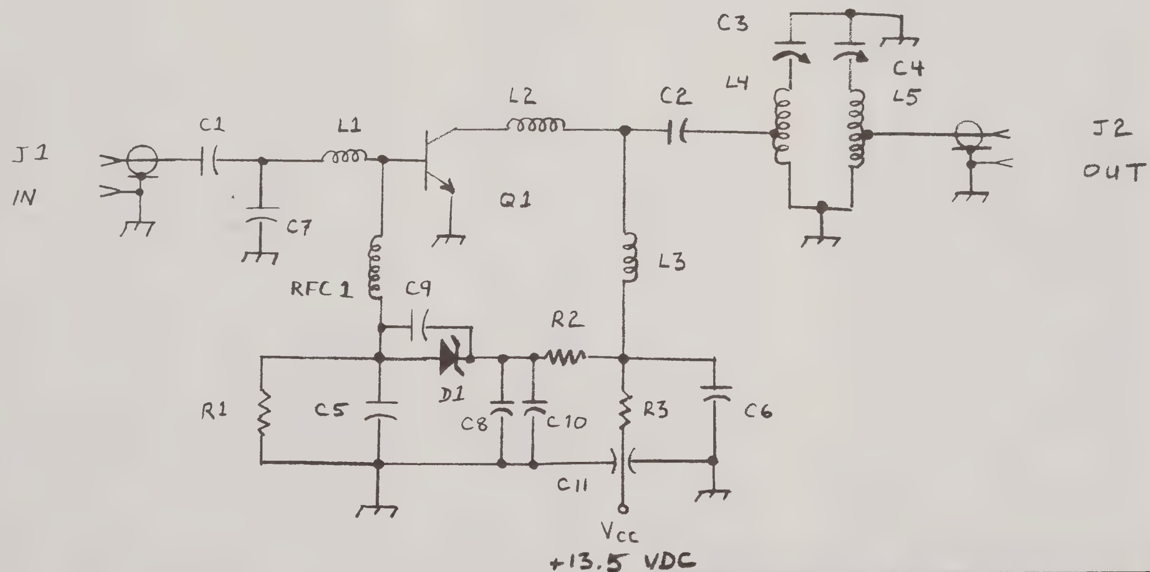

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1.2 GHz Ampli-Filter
SCHEMATIC DIAGRAM

SIZE | CODE IDENT NO. | DRAWING NO. RF-1200-401
SCALE | SHEET 1 OF 1

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REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

Designation	Description
C1,2	Chip Capacitor, ATC Type 100B, 100 pf
C3,4	Ceramic Piston Trimmer Capacitor, Triko 202-08M, 1 - 5 pf
C5,6	Microstripline Capacitor, 30 ohm Z_o, $\lambda/4$ at 1.2 GHz (see PC Artwork RF-1200-601)
C7	Microstripline Capacitor, 50 ohm Z_o, $\lambda/8$ at 1.2 GHz (see PC Artwork RF-1200-601)
C8	Microstripline Capacitor, 30 ohm Z_o, $\lambda/8$ at 1.2 GHz (see PC Artwork RF-1200-601)
C9,10	Miniature ceramic disc capacitor, 0.01 uf
C11	Ceramic Feedthru Capacitor, 1000 pf. Erie 2404-000-X5U0-102P
D1	Zener Diode, 9.1V ± 5% 400 mW, 1N5239
J1,2	SMA Receptical, E. F. Johnson 142-0298-001
L1-5	Microstripline Inductor, 50 ohm Z_o (see PC Artwork RF-1200-601)
Q1	Ion-implanted Microwave Silicon Bipolar Transistor, Hewlett-Packard HXTR-6105
R1,2	Carbon Composition Resistor, 470 ohm 10% ¼ watt
R3	Carbon Composition Resistor, 120 ohm 10% ¼ watt
RFC1	Microstripline Inductor, 90 ohm Z_o, $\lambda/4$ at 1.2 GHz (see PC Artwork RF-1200-601)
Enclosure	Pomona 2901
Circuit Board	Microcomm RF-1200-601

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1.2 GHz Ampli-Filter
PARTS LIST

SIZE	CODE IDENT NO.	DRAWING NO.
		RF-1200-501
SCALE		SHEET 1 OF 1

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CIRCUIT DESCRIPTION (Continued from page 5 - 1)

R3 serves to limit the collector current of Q1, which is applied via a similar network of microstriplines (L3 and C6). Operating potential is applied from the groundplane side of the printed circuit board, through feedthru capacitor C11. It must be noted that operating potential (12 to 15 VDC) applied to C11 must be <u>positive</u> with respect to ground. Reverse-polarity will cause catastrophic damage to Q1. Similarly, the power supply used must be well regulated, and free from turn-on and turn-off transients.

As an aid to component identification, troubleshooting and maintenance, the following pages detail the fabrication of the RF-1200 Ampli-Filter, as well as indicating typical performance characteristics as viewed on a network analyzer and spectrum analyzer.

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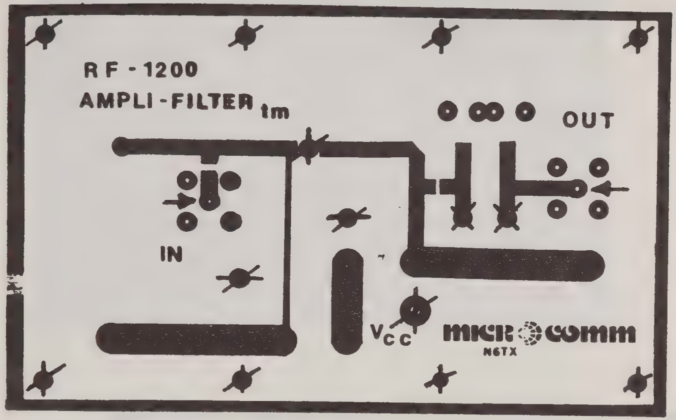

#56 14 plcs.

#65 2 plcs.

#27 10 plcs.

Small eyelet to groundplane, 2 plcs.

→ Counter-sink groundplane metallization with 1/8 " twist drill, 2 plcs.

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1.2 GHz Ampli-Filter

DRILLING INSTRUCTIONS

SIZE	CODE IDENT NO.	DRAWING NO.
		RF-1200-701A
SCALE 1 : 1		SHEET 1 OF 1

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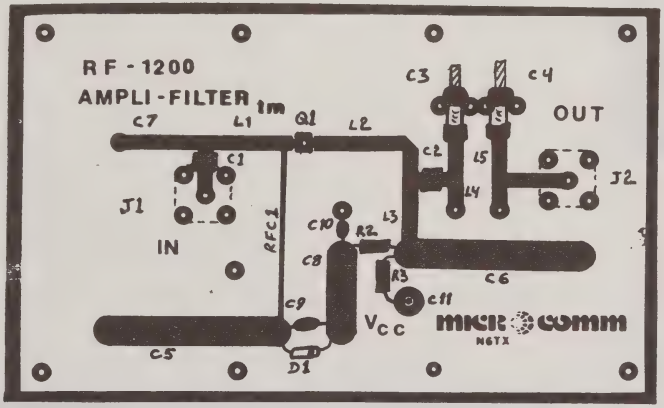

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1.2 GHz Ampli-Filter
ASSEMBLY DRAWING

SIZE	CODE IDENT NO.	DRAWING NO.
		RF-1200-801A
SCALE 1 : 1		SHEET 1 OF 1

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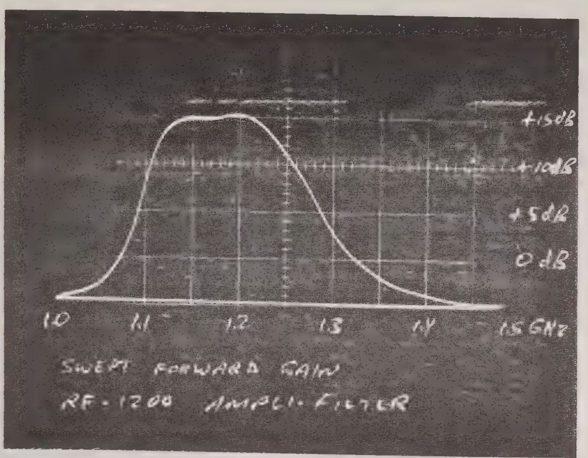

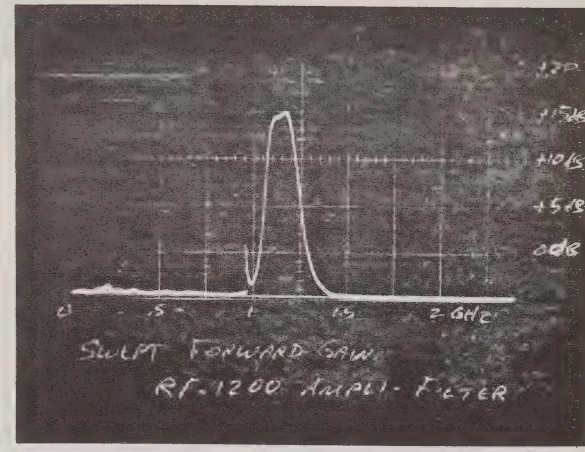

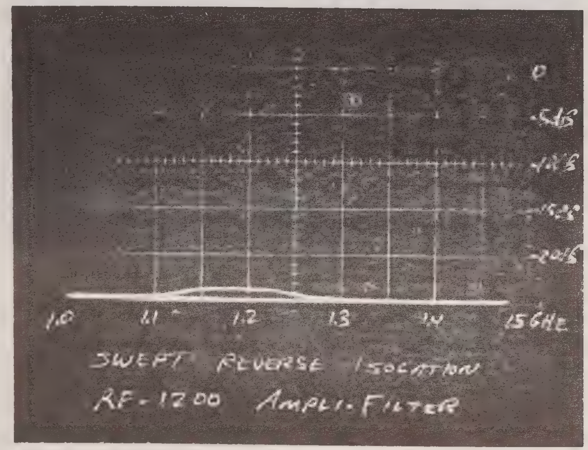

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1.2 GHz Ampli-Filter

SWEPT FREQUENCY RESPONSE

SIZE	CODE IDENT NO.	DRAWING NO.	
		RF-1200-901	
SCALE		SHEET 1 OF 1	

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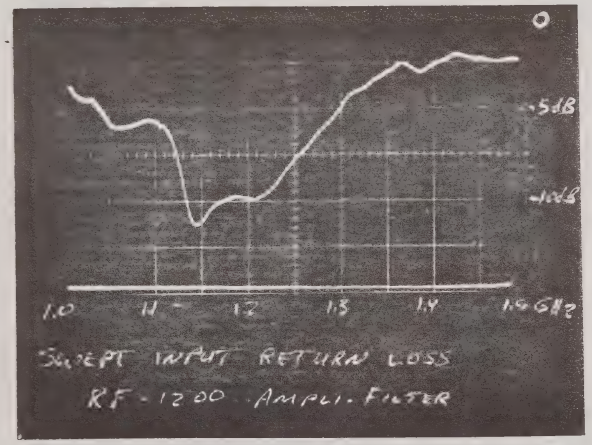

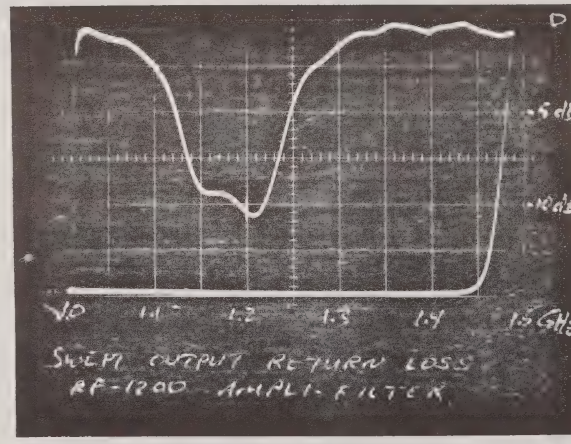

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1.2 GHz Ampli-Filter
SWEPT RETURN LOSS

SIZE	CODE IDENT NO.	DRAWING NO.
		RF-1200-902
SCALE		SHEET 1 OF 1

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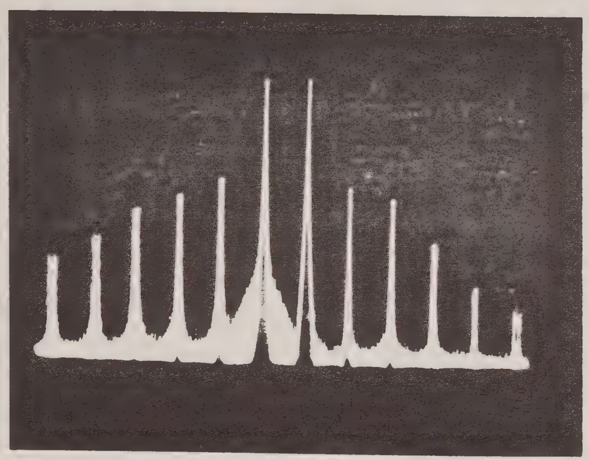
LTR	DESCRIPTION	DATE	APPROVED



TEST CONDITIONS:

V_{cc} = +13.5 VDC

F_c = 1.2 GHz

Δf = 1 MHz/cm

P out = +13 dBm/tone (80 mW PEP)

IMD_3 = -22 dB

therefore Third Order Intercept Point = +24 dBm

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1.2 GHz Ampli-Filter
TWO-TONE TEST

SIZE	CODE IDENT NO.	DRAWING NO.
		RF-1200-903
SCALE		SHEET 1 OF 1

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SECTION 6

LOCAL OSCILLATOR LO-1270

INTRODUCTION

The LO-1270 Local Oscillator is used in the RX-4200 Module Set to heterodyne against the amplified and filtered 1200 MHz first IF, creating a second IF frequency of 70 MHz. The LO-1270 provides 5 mW (+7 dBm) of 1270 MHz crystal-controlled output, with typically 40 dB of spurious rejection and 0.002% frequency tolerance. Microstripline construction is utilized, output is via a type SMA receptical, internal Zener regulation of the first (oscillator) stage is provided, and the unit is fully RF shielded by its enameled die-cast aluminum enclosure. The LO-1270 draws typically 60 mA from a +13.5 VDC power source.

CIRCUIT DESCRIPTION

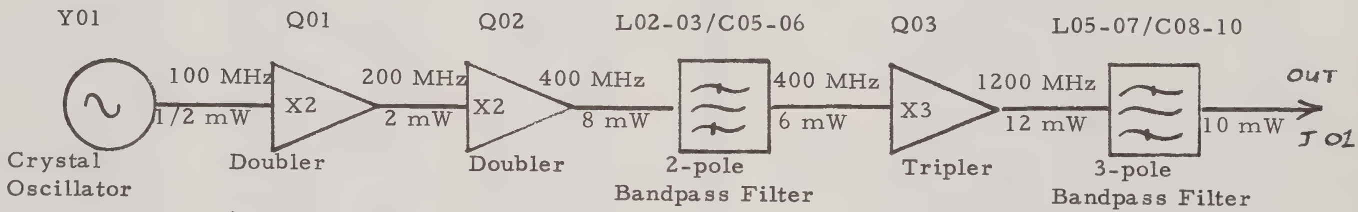
A functional block diagram of the LO-1270 is provided in Figure LO-1200-301. The module is shown schematically in Figure LO-1200-401, with parts list appearing on the page following.

Oscillator Module Y01 is a high-stability crystal overtone oscillator producing -3 dBm (1/2 mW) of output near 105 MHz. This assembly requires a regulated +9 VDC supply, which is furnished by Zener Diode D01, current limiting resistor R01 and bypass capacitor C01. The output port of Y01 exhibits DC continuity to ground, which is essential in providing a bias return for the following stage.

At the input to Q01, a common-emitter Class C doubler stage, trimmer capacitor C16 resonates Y01's inductive output link, affording a double-tuned interstage transformer between the oscillator stage and the first multiplier. The output circuit of Q01 consists of microstrip inductor L01 resonated by piston trimmer capacitor C04 near 211 MHz. Collector current for Q01 is limited to 10 mA by R02. This resistor, along with bypass capacitor C02 and feedthru capacitor C13, provides power supply decoupling for the first multiplier stage.

Q02 serves as a second Class C common-emitter doubler. Its input is coupled via C03, which is tapped down on L01 for impedance matching. R03 provides base bias return. The collector is shunt-fed by R06, and supply decoupling is via feedthru capacitor C14 along with R04. Collector current is approximately 15 mA. The output circuit for Q02 consists of two poles of microstripline

(Circuit Description continued on page 6 - 5)



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L-Band Local Oscillator Chain
BLOCK DIAGRAM

SIZE	CODE IDENT NO.	DRAWING NO.
		LO-1200-301

SCALE		SHEET 1 OF 1

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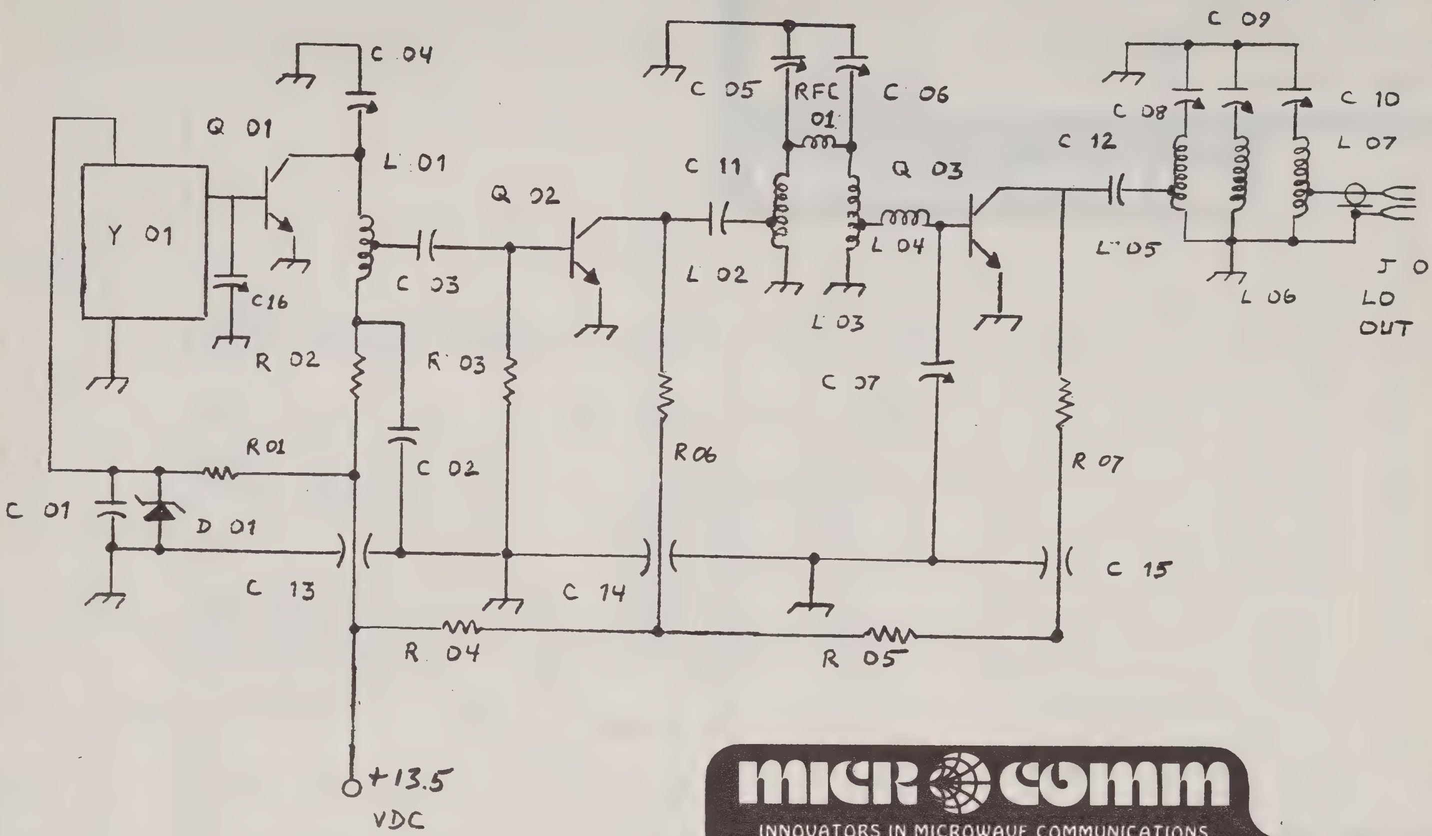

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L-Band Local Oscillator Chain
SCHEMATIC DIAGRAM

SIZE	CODE IDENT NO.	DRAWING NO.
		LO-1200-401

SCALE SHEET 1 OF 1

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REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

Designation	Description
C01 - 03	Miniature Ceramic Disc Capacitor, 0.01 uf
C04 - 10	Ceramic Piston Trimmer Capacitor, Triko 202-08M, 1 - 5 pf
C11 - 12	Chip Capacitor, ATC Type 100 B, 100 pf
C13 - 15	Ceramic Feedthru Capacitor, Erie 2404-000-X5U0-102P, 1000 pf
C16	Ceramic Trimmer Capacitor, 9 - 35 pf
D01	Zener, 9.1 V ± 5%, 400 mW. 1N5239
J01	SMA Receptical, E. F. Johnson 142-0298-001
L01-07	Microstripline Inductor (see PC Artwork LO-1200-601)
Q01 - 03	UHF Silicon Bipolar Transistor, Motorola MRF-901
R01	Carbon Composition Resistor, 180 ohm 10% 1/4 watt
R02, 06, 07	Carbon Composition Resistor, 470 ohm 10% 1/4 watt
R03	Carbon Composition Resistor, 330 ohm 10% 1/4 watt
R04 - 05	Carbon Composition Resistor, 10 ohm 10% 1/4 watt
RFC01	Miniature Molded Choke, Nytronics Mini-ductor, 0.33 uh
Y01	Crystal Oscillator Assembly, International Crystal OE-5, 90 to 130 MHz (Output Frequency ÷ 12)
Enclosure	Pomona 2901
Circuit Board	Microcomm LO-1200-601

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L-Band Local Oscillator Chain
PARTS LIST

SIZE	CODE IDENT NO.	DRAWING NO.
		LO-1200-501

SCALE | SHEET 1 OF 1

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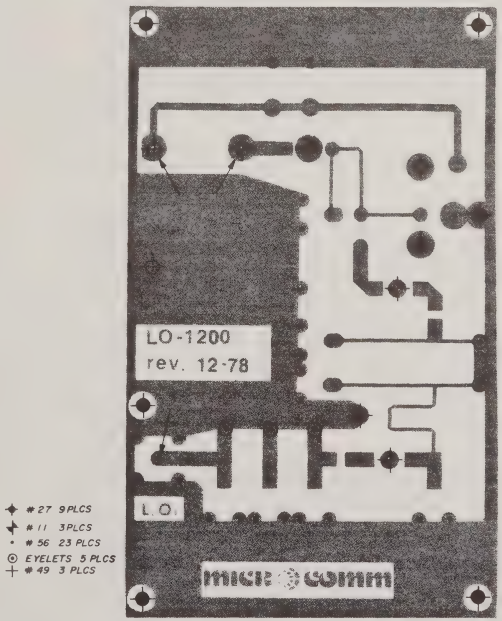
inductor (L02, 03) resonated near 423 MHz by two piston trimmer capacitors (C05, 06). Inductive coupling between filtering poles, provided by RFC01, suppresses higher harmonics at the output of the second doubler. Conversion gain of each doubler, exclusive of filter losses, is on the order of +5 dB.

Class C common emitter tripler Q03 operates as a parametric multiplier. Its input is applied via a low-pass filter consisting of microstripline inductor L04 and piston trimmer capacitor C07. The series inductance of C07 is such that it self-resonates at the desired output frequency, maximizing gain at that particular frequency by driving the base impedance of Q03 negative. Shunt collector feed for the active tripler is via R07, with DC decoupling provided by R05 and C15. Collector current for Q03 is on the order of 15 mA, and the stage operates at approximately 3 dB gain.

The output of Q03 is capacitively coupled via C12 into a 3-pole output filter consisting of microstripline inductors L05, 06, and 07, resonated at 1270 MHz by piston trimmer capacitors C08, 09, and 10. Coupling between filter poles is capacitive, resulting from the proximity of the piston trimmer stators. The 5 mW LO output appears at J01.

As an aid to component identification, troubleshooting and maintenance, the following pages detail the fabrication of the LO-1270 Oscillator. Should retuning ever be required, the appropriate test configuration is also indicated, along with a typical output spectrum photograph.

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



Drilling diagram for the etched side of the circuit board. In addition to the etched side, the three locations marked with arrows are also countersunk on the ground-plane side.

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L-Band Local Oscillator Chain
DRILLING INSTRUCTIONS

SIZE	CODE IDENT NO.	DRAWING NO.
		LO-1270-701
SCALE 1 : 1		SHEET 1 OF 1

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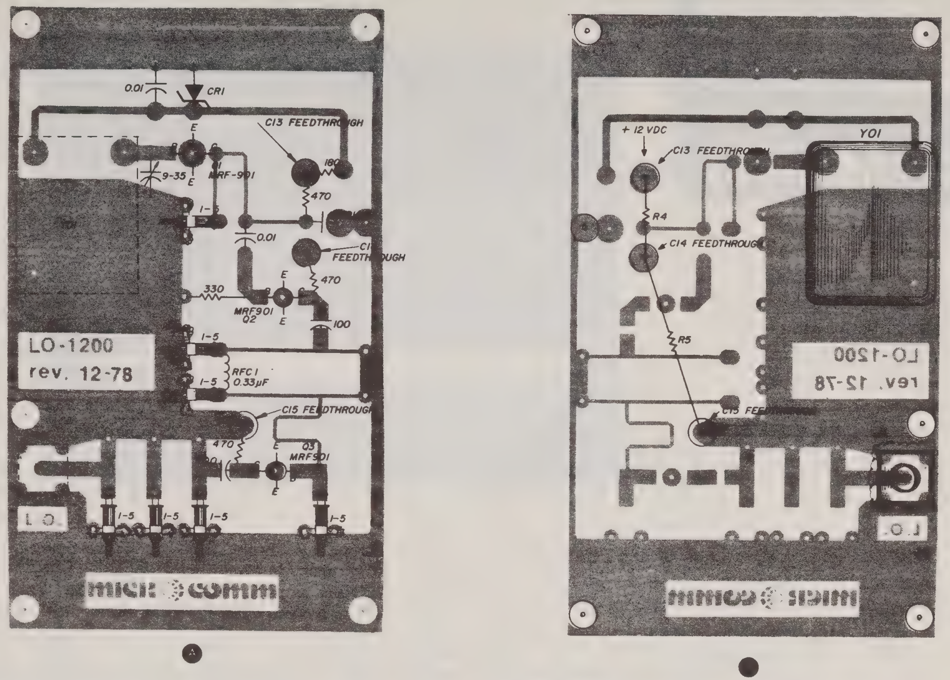
REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



Component placement diagrams for the microstripline and groundplane sides.

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L-Band Local Oscillator Chain
ASSEMBLY DRAWING

SIZE	CODE IDENT NO.	DRAWING NO.
		LO-1200-801

SCALE 1 : 1 SHEET 1 OF 1

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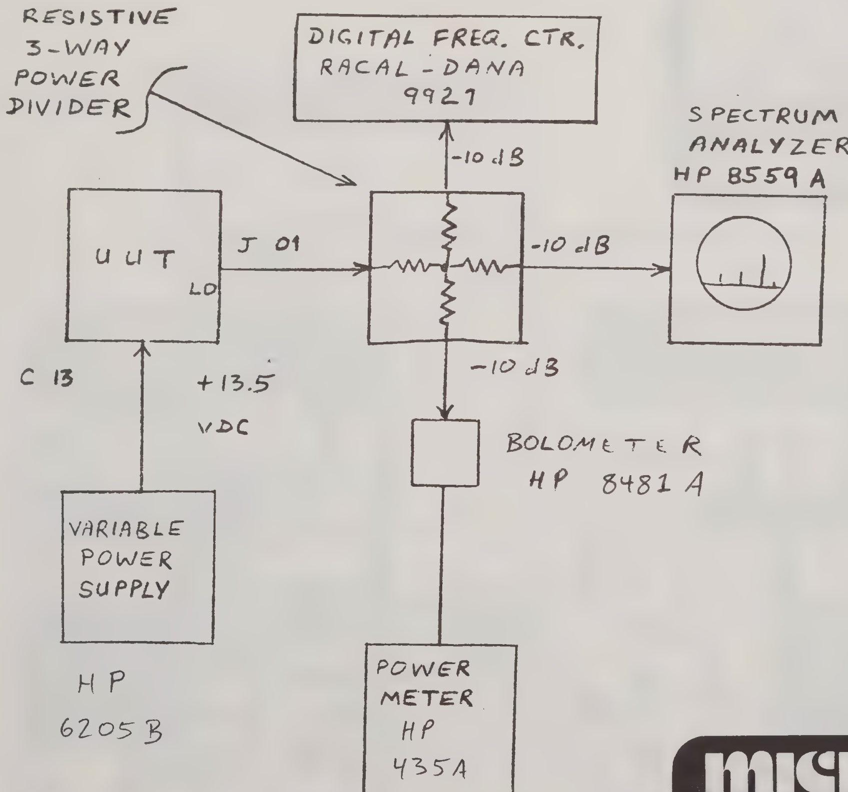
REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



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APPROVALS	DATE
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L-Band Local Oscillator Chain
TEST CONFIGURATION

SIZE	CODE IDENT NO.	DRAWING NO.
		LO-1200-901
SCALE		SHEET 1 OF 1

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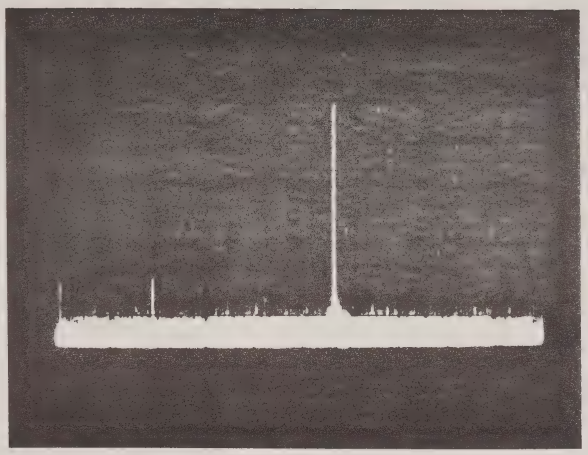
REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



Vertical Axis: 10 dB/cm
Horizontal Axis: DC- 2 GHz; 200 MHz/cm

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L-Band Local Oscillator Chain
TYPICAL OUTPUT SPECTRUM

SIZE	CODE IDENT NO.	DRAWING NO.
		LO-1200-902
SCALE		SHEET 1 OF 1

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SECTION 7

MIXER/AMPLIFIER MA-1200

INTRODUCTION

The MA-1200 Mixer/Amplifier performs the second downconversion in the Microcomm RX-4200 Module Set. It receives a 1270 MHz Local Oscillator input from the LO-1270, and an amplified, filtered 1200 MHz signal input from the two cascaded RF-1200 Ampli-Filters. The MA-1200 contains a diode doubly-balanced mixer, three stages of 70 MHz IF amplification, and filtering to establish the 40 MHz IF bandwidth required for DOMSAT video reception. The module provides well in excess of 20 dB conversion gain, is fully shielded by its enameled, die-cast aluminum enclosure, and draws roughly 60 mA from a 13.5 VDC power source.

CIRCUIT DESCRIPTION

The MA-1200 Mixer/Amplifier is shown schematically in Figure MA-1200-401, with parts list appearing on the page following.

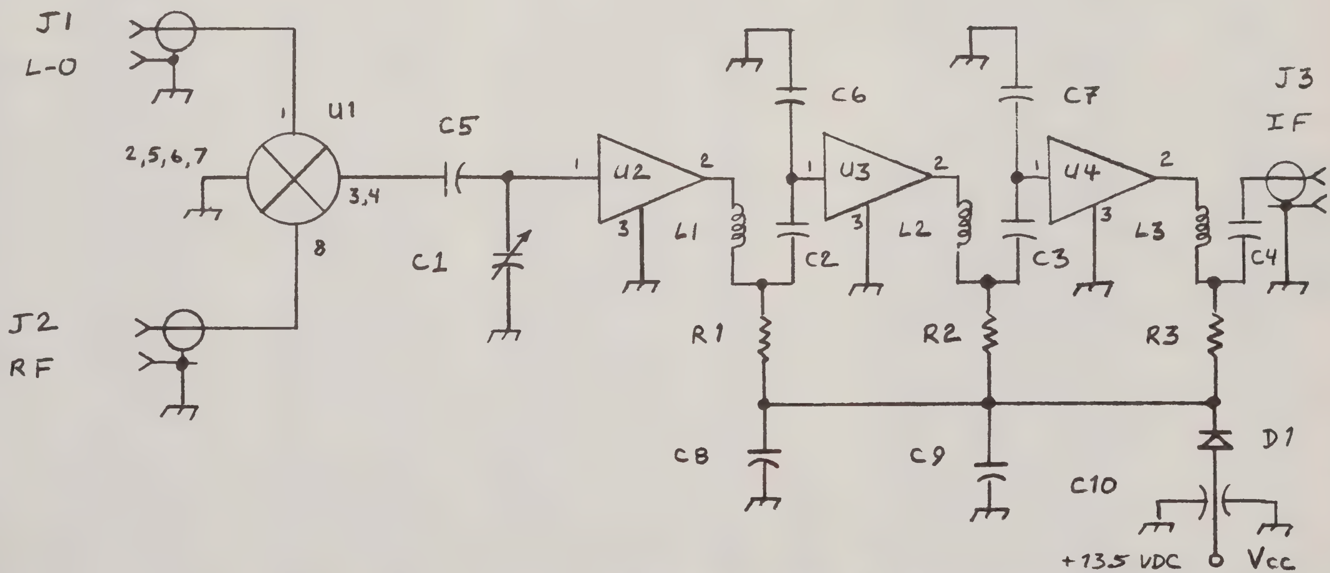
Local Oscillator injection from the LO-1270 is applied to J1, and the 1200 MHz input signal to J2. Both these signals are applied to Diode Double-Balanced Mixer U1, with the DIP Mixer's RF and LO pins reversed to minimize conversion loss at the particular operating frequency employed. The IF output from Pins 3 and 4 of U1 is applied to the input of First Amplifier stage U2 via a capacitive voltage divider (C5 and C1) the tuning of which minimizes noise figure.

The second and third amplifier stages utilize hybrid amplifiers similar to U2, but exhibiting higher output levels. The three amplifier stages U2, U3 and U4 are cascaded via series-resonant LC circuits (L1/C2, L2/C3, and L3/C4) which establish the selectivity characteristics of the 70 MHz IF amplifier string. Capacitors C6 and C7 shunting the inputs of amplifier hybrids U3 and U4 serve to roll off gain more rapidly at the high frequency skirt.

Collector current to the three amplifier hybrids is shunt-fed and limited by resistors R1, R2 and R3. Disc capacitors C8 and C9, and feedthru capacitor C10, provide power supply decoupling, while diode D1 protects the amplifier hybrids from reverse supply polarity. The downconverted and filtered FM video signal appearing at J3 is normally applied directly to a baseband processor for demodulation.

This Section details the fabrication of the MA-1200 Mixer/Amplifier as an aid to component identification, troubleshooting and maintenance. A test configuration and typical response curve for swept frequency testing are also shown.

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



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MIXER/AMPLIFIER SCHEMATIC

SIZE	CODE IDENT NO.	DRAWING NO.
		MA-1200-401
SCALE		SHEET 1 OF 1

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REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

Designation	Description
C1	Piston Trimmer Capacitor, 1 - 8.5 pf, Triko 203-09M
C2 - C7	Miniature Dipped Silver-Mica Capacitor, 50 pf
C8 - C9	Miniature Ceramic Disc Capacitor, 0.01 uf
C10	Ceramic Feedthru Capacitor, 1000 pf, Erie 2404-000-X5UO-102P
D1	Silicon General Purpose Diode, 1N914 or equivalent
J1 - J3	SMA Receptical, E. F. Johnson 142-0298-001
L1 - L3	Miniature molded RF Choke, 0.15 uH
U1	DIP Double-Balanced Mixer, Englemann Microwave MLP-102
U2	Wideband Hybrid Amplifier, Motorola MWA-110
U3 - U4	Wideband Hybrid Amplifier, Motorola MWA-120
R1	Carbon Composition Resistor, 1 K ohm 10% 1/4 watt
R2 - R3	Carbon Composition Resistor, 330 ohm 10% 1/4 watt
Enclosure	Pomona 2901
Printed Circuit Board	Microcomm MA-1200-601

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MIXER/AMPLIFIER PARTS LIST

SIZE	CODE IDENT NO.	DRAWING NO.
		MA-1200-501

SCALE		SHEET 1 OF 1

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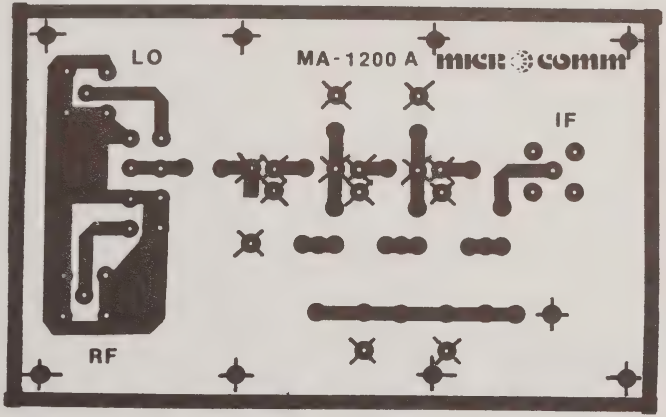

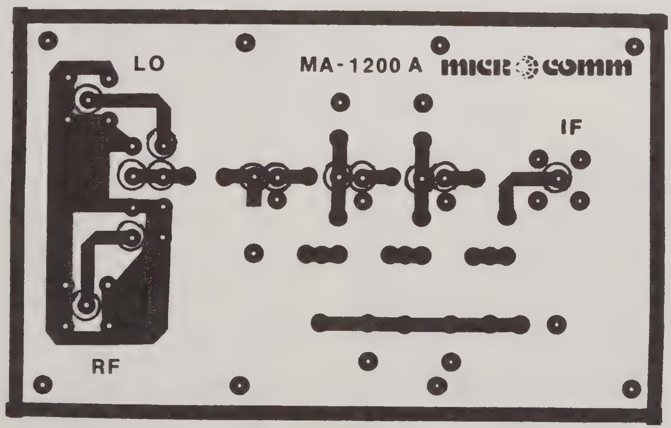

#27 9 PLCS

#56 24 PLCS

#65 14 PLCS

COUNTER-SINK GROUNDPLANE SIDE
13 PLCS

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

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APPROVALS	DATE
SS	8-79

MIXER/AMPLIFIER
DRILLING INSTRUCTIONS

SIZE	CODE IDENT NO.	DRAWING NO.
		MA-1200-701
SCALE		SHEET 1 OF 1

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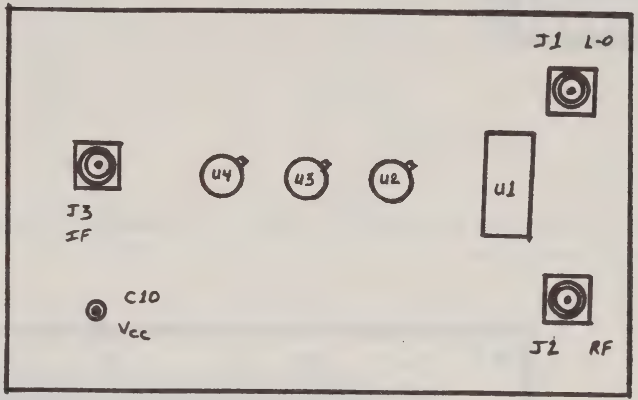
LTR	DESCRIPTION	DATE	APPROVED



COMPONENTS MOUNTED ON GROUNDPLANE SIDE OF PRINTED CIRCUIT BOARD

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INNOVATORS IN MICROWAVE COMMUNICATIONS

APPROVALS	DATE
SC	8-79

MIXER/AMPLIFIER
ASSEMBLY DRAWING

SIZE	CODE IDENT NO.	DRAWING NO.
		MA-1200-801

SCALE 1:1 SHEET 1 OF 2

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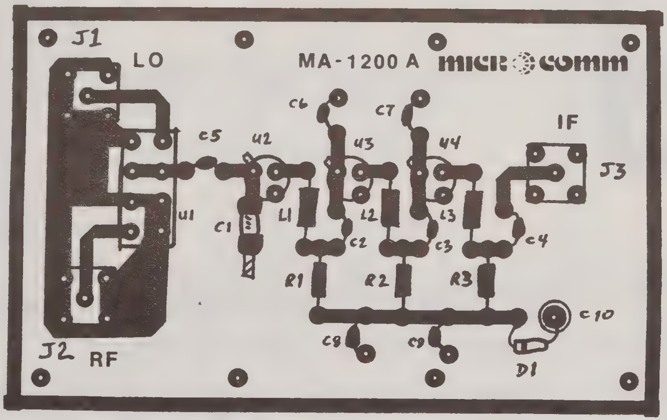
REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED



COMPONENTS MOUNTED ON TRACE SIDE OF PRINTED CIRCUIT BOARD

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APPROVALS	DATE
SS	8-79

MIXER/AMPLIFIER
ASSEMBLY DRAWING

SIZE	CODE IDENT NO.	DRAWING NO.
		MA-1200-801
SCALE 1 : 1		SHEET 2 OF 2

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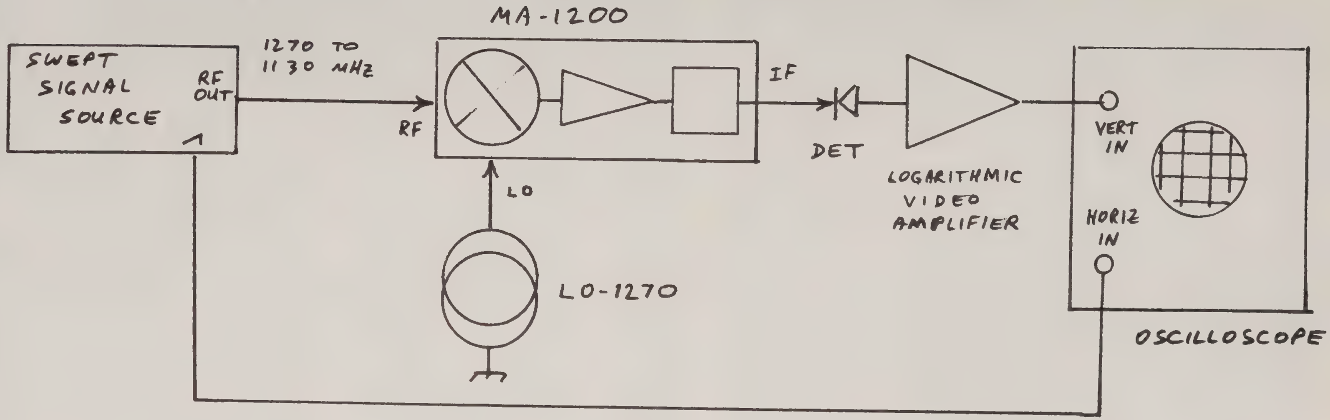
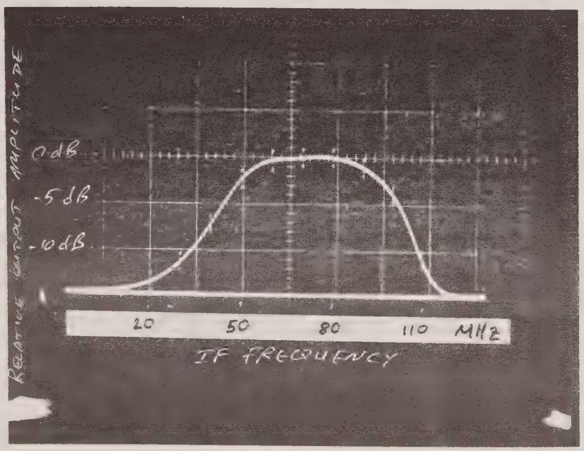
REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED





MICROCOMM
INNOVATORS IN MICROWAVE COMMUNICATIONS

APPROVALS	DATE
SS	8-79

MIXER/AMPLIFIER
Swept Frequency Response Test

SIZE	CODE IDENT NO.	DRAWING NO.
		MA-1200-901

SCALE | SHEET 1 OF 1

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SECTION 8

BASEBAND PROCESSOR BB-4200

INTRODUCTION

The Microcomm RX-4200 Module Set processes a received DOMSAT video signal through heterodyne downconversion, amplification and filtering, as detailed in the foregoing sections. The 70 MHz wideband FM composite available at the output of the last downconversion module (the MA-1200 Mixer/Amplifier) contains all necessary signal components to recover the program audio and video, but not in a format readily amenable to display.

This Section contains design and construction details for a Baseband Processor board which is entirely compatible with the RX-4200 Module Set, and which users of the Microcomm Modules may readily duplicate to complete their systems. The circuitry is based in part on earlier designs by H. T. Howard of Stanford University,* and his advice and assistance are gratefully acknowledged.

It should be noted that in the absence of a complete Baseband Processor, the proper operation of the balance of a TVRO Terminal can readily be verified through either SCPC Audio Reception or Slope Detection.

SCPC (Single Channel Per Carrier) is a multiplexing technique whereby several independent uplink signals of narrow-band characteristics may share a single satellite transponder (actually, linear translator) by each transmitting a carrier plus modulation sidebands on a separate assigned frequency within the passband. Freedom from intermodulation distortion is assured by operating each SCPC uplink at a power level well below the point at which transponder gain compression would occur. This situation resembles the linear translator passband sharing which occurs on the radio amateur satellites.

As this is being written (August 1979), there are two SCPC audio channels of interest to the experimenter which are being relayed via RCA Satcom F2 (SSP 119.0 °W) on Transponder 3 (vertical), and four on WESTAR I (SSP 99.0° W) Transponder 6 (horizontal). These audio services (used by the Alaska Video distribution project and National Public Radio, respectively) all utilize frequency modulation with 75 KHz peak deviation and 15 KHz maximum audio frequency (a Deviation Ratio of 5), and are thus compatible with FM Broadcast receivers. The bandwidth of the 70 MHz second IF in the RX-4200 Module Set

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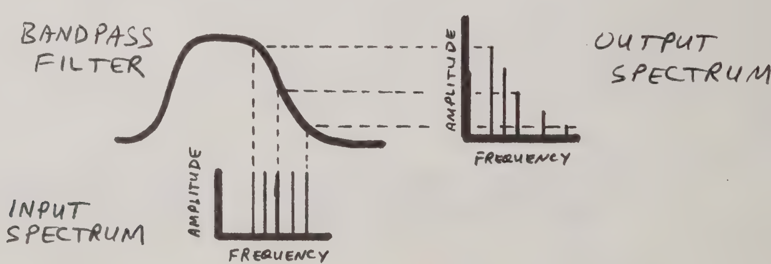
* H. T. Howard, "The Howard Terminal" (Manual and Videotape), TVRO Plans, P. O. Box G, Arcadia OK 73007.

is sufficiently wide that an FM Broadcast receiver can be readily tuned to the bottom of its band (88 MHz), coupled to the 70 MHz IF output of the MA-1200 Mixer/Amplifier and, through careful tuning of the First Local Oscillator across the required channel, SCPC Audio can be recovered.

Note that, although the EIRP of a single SCPC channel will be a fraction of that associated with the satellite transponder used (remember, the transponder power is being shared), the narrow bandwidth of the signal being recovered (typically 200 KHz) affords roughly 23 dB signal-to-noise advantage over that achieved with full-transponder video bandwidths (40 MHz). This suggests that adequate SCPC Audio reception can be achieved utilizing antennas far smaller than those required for video reception, and in fact a 1.2 meter diameter parabolic reflector proves quite acceptable for the previously mentioned signals at the author's location.

Even though recovering SCPC Audio helps to verify proper receiver operation and allows a certain degree of antenna optimization, few experimenters are satisfied with the operation of their TVRO Terminals until they have begun to recover viewable video. This requires construction of a baseband processor such as the one to be described below, but as a first step in viewing satellite video one may wish to employ the technique known as slope detection. Here the 70 MHz output from the downconversion module system is fed directly into the antenna terminals of a broadcast television receiver, whose tuner is set to Channel 4. True, the satellite video format is wideband-FM, with a 40 MHz channel bandwidth, while the TV receiver is designed to accept a vestigal-sideband AM video signal, with a channel bandwidth of 6 MHz. Nontheless there will be crude but discernible video present if a carefully fine-tuned satellite TV channel is displayed on a standard TV receiver.

What is happening is best described graphically, as in the illustration below. The input selectivity curve of the TV tuner essentially transforms the FM sidebands into a pseudo-AM signal, by varying the amplitude of signal components at various different frequencies. The amplitude linearity is a function of the filter skirts in the tuner, and is likely to be poor at best; hence, an erratic video signal which is difficult to synchronize. Nonetheless, recognizable video can be received with no baseband processor whatever, and this provides the experimenter with considerable opportunity for system testing and optimization prior to actual baseband processor construction.



CIRCUIT DESCRIPTION

The Baseband Processor assembly is summarized in the Block Diagram on page 8-4, and shown schematically on pages 8-5 through 8-7. The required components are listed on pages 8-8 and 8-9. Although Microcomm does not supply either completed Baseband Processor units or kits of parts for this design, those experimenters who prefer not to assemble their own equipment will find several commercial receivers on the market in the months ahead which utilize this baseband processor design in conjunction with the Microcomm downconversion modules.

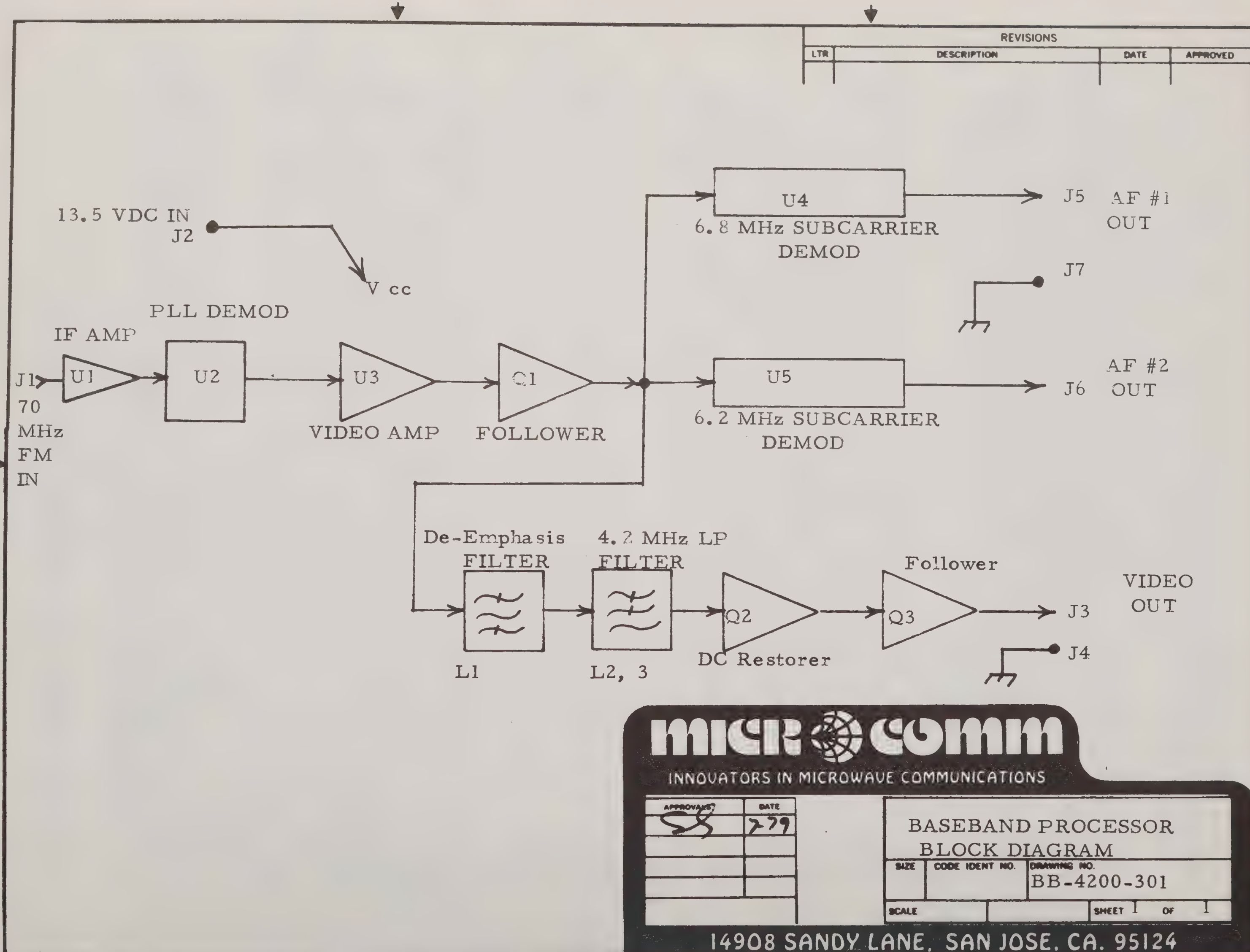
The wideband FM satellite composite signal, having been downconverted to 70 MHz, is first applied to wideband amplifier hybrid U1, where it is amplified linearly prior to demodulation. Linear processing of the satellite composite signal during downconversion, amplification and filtering is essential for spurious-free demodulation in the Phase-Locked Loop Demodulator (U2); hence it may be desirable in those TVRO installations employing either unusually high-gain antennas or inordinately high LNA gain to either pad the input to the receiver, the input to the baseband processor, or perhaps to eliminate U1 altogether. If U1 is utilized, then the input power level to the baseband processor should not be allowed to exceed -20 dBm (20 mV referenced to 50 ohms).

The FM waveform is demodulated in U2, a monolithic PLL which is tuned to 70 MHz carrier frequency by R7, R8 and C10. C5 and C6 form a loop filter to limit the maximum frequency excursion of the PLL to the expected deviation of the incoming FM signal. R3 provides a current source which determines the range of amplitude levels over which the PLL will lock.

The PLL output is an extremely feeble video waveform. It is DC Coupled to amplifier microcircuit U3 by a resistive voltage divider network (R9 and R14) which both establishes the appropriate input bias levels for the video amplifier and assures that the PLL output will not drive the video amplifier into clipping. R13 establishes the gain of the video amplifier, and is chosen to provide a standard 1 volt peak-to-peak video level into 75 ohms at the video output pin of the baseband processor. A jumper wire allows selection of either output polarity from the video amplifier IC, thus allowing the user to compensate for the presence or absense of FM spectrum inversion in the downconversion stages which precede the baseband board.

Q1 is an emitter-follower stage, which buffers the selected high-impedance output of the video amplifier, providing three distinct low-impedance outputs, to drive the video processing circuitry, and subcarrier demodulators for the two audio channels associated with DOMSAT video.

(Circuit Description continued on page 8-10.)


REVISIONS
LTR
DESCRIPTION
DATE
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13.5 VDC IN
J2
V cc
PLL DEMOD
IF AMP
J1
70
MHz
FM
IN
U1
U2
U3
VIDEO AMP
Q1
FOLLOWER
U4
6.8 MHz SUBCARRIER
DEMOD
J5
AF #1
OUT
J7
U5
6.2 MHz SUBCARRIER
DEMOD
J6
AF #2
OUT
De-Emphasis
FILTER
L1
4.2 MHz LP
FILTER
L2, 3
Q2
DC Restorer
Follower
Q3
J3
VIDEO
OUT
J4
MICROCOMM
INNOVATORS IN MICROWAVE COMMUNICATIONS
APPROVALS
DATE
7-79
BASEBAND PROCESSOR
BLOCK DIAGRAM
SIZE
CODE IDENT NO.
DRAWING NO.
BB-4200-301
SCALE
SHEET 1 OF 1
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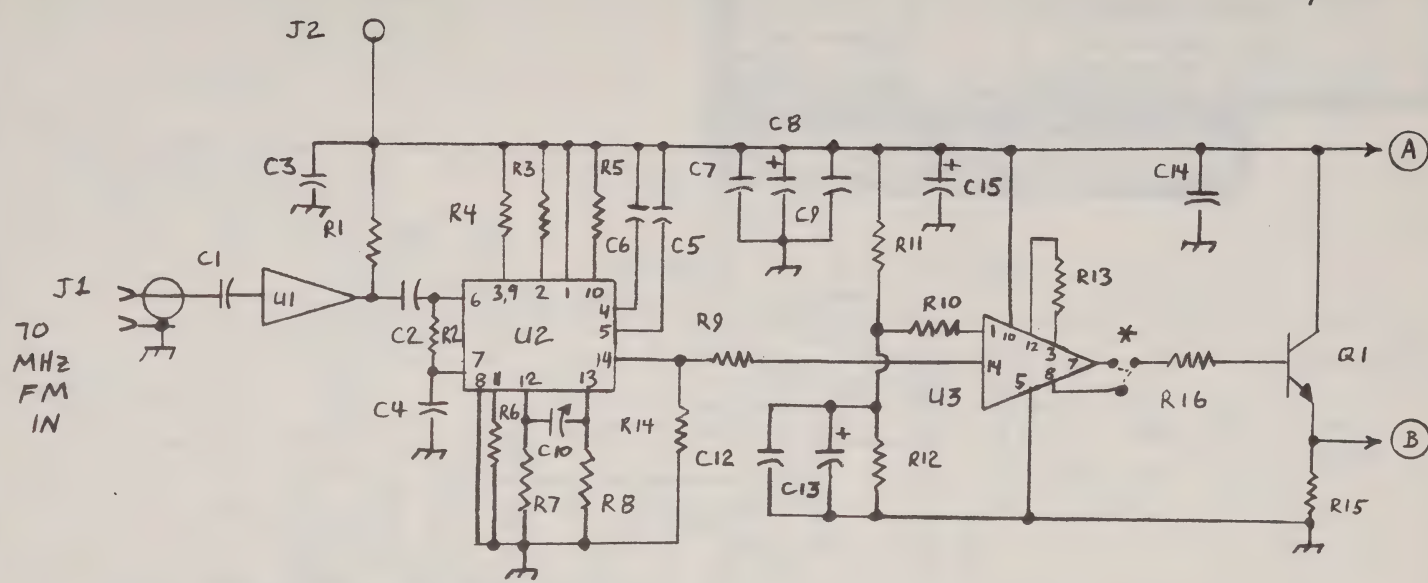
REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	ADD R9A	2/08/79	SE
B	DC COUPLING	3/09/79	SE



* JUMPER PIN 7 TO C16 TO INVERT ; PIN 8 TO C16 FOR NON-INVERTING OUTPUT.

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BASEBAND PROCESSOR SCHEMATIC

SIZE	CODE IDENT NO.	DRAWING NO.
		BB-4200-401
SCALE		SHEET 1 OF 3

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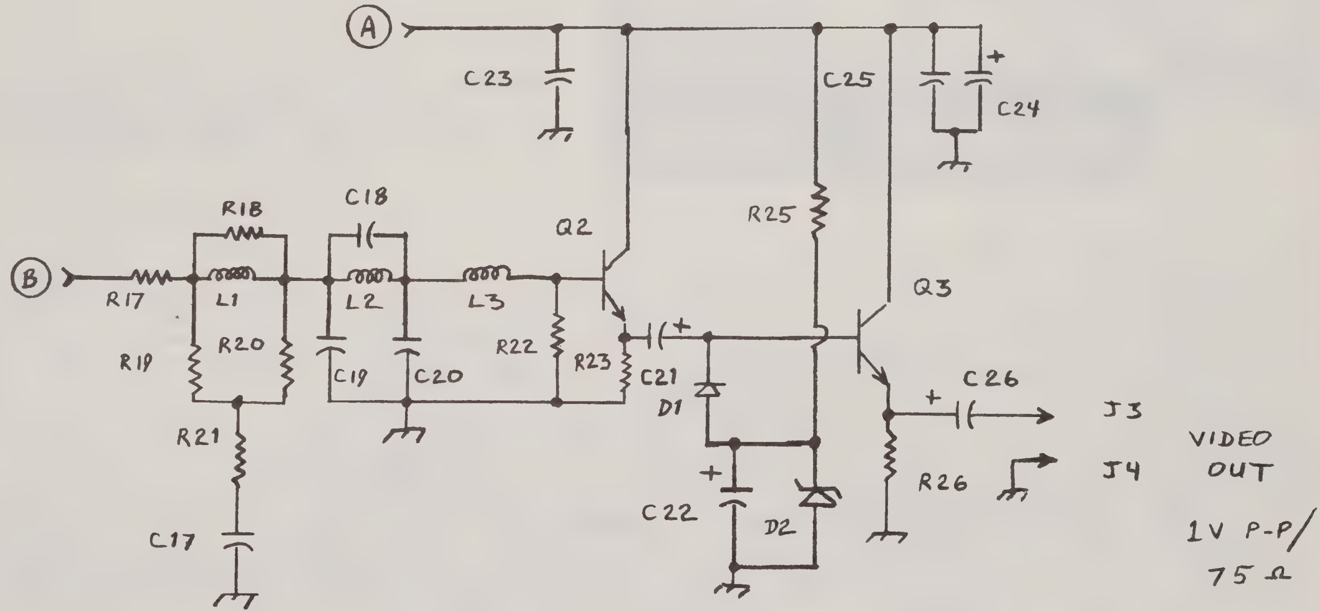
REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	DEL. R24	3/08/79	SK



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INNOVATORS IN MICROWAVE COMMUNICATIONS

APPROVALS	DATE
SK	7-79

BASEBAND PROCESSOR SCHEMATIC

SIZE	CODE IDENT NO.	DRAWING NO.
		BB-4200-401
SCALE		SHEET 2 OF 3

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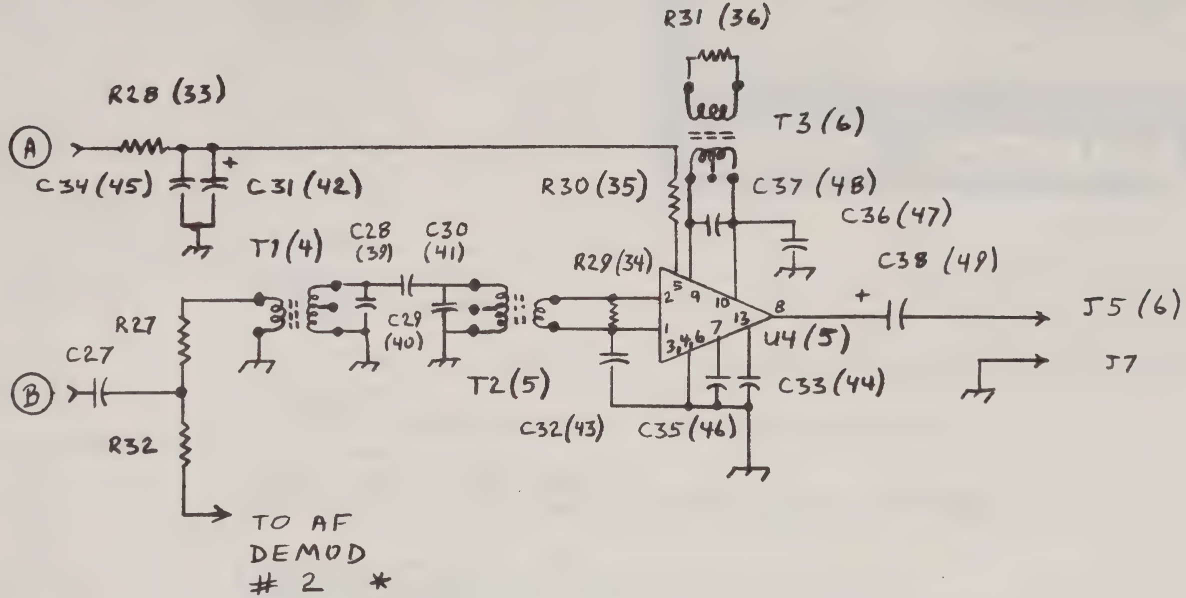

* AF DEMODS #1 AND 2
ARE IDENTICAL CIRCUITRY.
TUNE FOR 6.8 AND 6.2 MHZ
SUBCARRIERS RESPECTIVELY.
PART NUMBERS IN PARENS
APPLY TO AF #2.

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

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APPROVALS	DATE
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BASEBAND PROCESSOR SCHEMATIC

SIZE	CODE IDENT NO.	DRAWING NO.
		BB-4200-401
SCALE		SHEET 3 OF 3

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C1, 2, 28, 30, 37, 19, 39, 41, 48	Dipped Silver-Mica Capacitor, 100 pf
C3, 4, 7, 9, 12, 14, 23, 25, 27, 32, 33, 34, 35, 43, 44, 45, 46	Miniature Ceramic Disc Capacitor, 0.01 uf
C5, 6, 29, 40	Dipped Silver-Mica Capacitor, 2 pf
C8, 13, 24, 31, 42	Electrolytic Capacitor, 100 uf 15 WVDC, end-mount
C10	Ceramic Trimmer Capacitor, 3.5 - 14 pf
C 15, 22, 26	Electrolytic Capacitor, 220 uf 15 WVDC, axial-lead
C17	Dipped silver-Mica Capacitor, 0.0047 uf
C18, 20	Dipped Silver-Mica Capacitor, 330 pf
C21, 38, 49	Electrolytic Capacitor, 1 uf 15 WVDC, axial-lead
C36, 47	Dipped Silver-Mica Capacitor, 10 pf
D1	Hot-Carrier Diode, Hewlett-Packard 5082-2811 or equivalent
D2	Zener Diode, 6 Volt, 400 mW
J1	SMA Female Receptical, E. F. Johnson 142-0298-001
J2, 3, 4, 5, 6, 7	Vector Pins
Q1, 2, 3	NPN Silicon RF Transistor, 2N2222 or equivalent
L1	Molded RF Choke, 100 uh
L2	Molded RF Choke, 2.7 uh
L3	Molded RF Choke, 4.7 uh

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

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Baseband Processor - Parts List

SIZE | CODE IDENT NO. | DRAWING NO. BB-4200-501

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	Carbon Composition Resistors, 1/4 W, 10%:
R1	330 ohm
R2, 4, 6, 15	1K ohm
R9, 14	18K ohm
R5	270 ohm
R7, 8, 3	10K ohm
R11	4.7 K ohm
R13, 12	3.9 K ohm
R16, 18, 23, 26, 29, 31, 34, 36	470 ohm
R17, 19, 20, 22, 27, 32	150 ohm
R21	47 ohm
R25	2.7 K ohm
R28, 33	82 ohm
R30, 35, 10	10 ohm

T1, 2, 3, 4, 5, 6	Miniature 10.7 MHz IF Transformer, Mouser Electronics 42IF126 or equivalent
U1	RF Amplifier Microcircuit, Motorola MWA-120
U2	Phase Locked Loop Microcircuit, Signetics NE-564
U3	Video Amplifier Microcircuit, Signetics NE592 or National LM-733
U4, 5	AF Demodulator Microcircuit, Motorola MC-1358, RCA CA-3065, or National LM-3065
Printed Citcuit Board	Microcomm BB-4200-601
Enclosure	Pomona 4226

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Baseband Processor - Parts List

SIZE	CODE IDENT NO.	DRAWING NO.
		BB-4200-501
SCALE		SHEET 2 OF 2

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CIRCUIT DESCRIPTION (Continued from page 8 - 3)

The video composite available at the emitter of Follower Q1 bears a number of types of severe distortion, as indicated in Oscilloscope Photo A on page 8 - 18, and several forms of filtering and clamping are necessary to transform the waveform to "clean" video such as that shown in Photo B on the same page.

Prior to uplink transmission, the satellite video has been pre-distorted in a pre-emphasis filter, the higher frequency components being boosted in amplitude by up to 13 dB,to better override system noise. Although such pre-emphasis improves overall video signal-to-noise ratio by roughly 3 dB, filtering at the receive end must cut back the gain at high video frequencies to avoid amplitude distortion. L1, C17, and R17 through 21 provide a de-emphasis circuit, formulated in accordance with CCIR Recommendation 405-1. A low-pass filter consisting of L2, L3, and C18 through 20 removes from the video waveform the 6.2 and/or 6.8 MHz subcarriers utilized for satellite audio transmission.

But the signal entering the base of Q2 still contains, superimposed upon the composite, de-emphasized and filtered video, a triangular waveform at 30 Hz, the "energy dispersal" waveform added to the uplink signal to decrease the spectral density of the downlink signal, thus minimizing interference with terrestrial microwave services. Removal of the energy-dispersal waveform is accomplished in a simple diode clamp circuit, or DC Restorer, consisting of Q2, D1 and their associated biasing components. The clamped signal is then buffered by emitter follower Q3, which provides a 1 volt peak-to-peak video output into a 75 ohm load impedance, to drive the video input of a recorder, monitor, or modulator as required.

As the two audio subcarrier demodulator circuits are identical except for the frequency to which they are tuned (6.2 or 6.8 MHz), only one will be described. The demodulated FM carrier (containing the audio subcarriers) is applied to a bandpass filter at the subcarrier frequency, consisting of T1, T2, and C28 through 30. The filtered audio subcarrier is then applied to quadrature-detector microcircuit U4, an FM Detector IC which also contains an audio preamplifier. T3 and C37 form the frequency-determining elements of the quadrature detector, and R31 reduces the Q of the tuned circuit to accomodate the 75 KHz peak deviation of the AF subcarrier. Audio de-emphasis at a 75 uSec time constant is accomplished by C35 in conjunction with a resistor internal to U4. The recovered audio from U4 approximates a level of 0 dBm into a 600 ohm load at maximum (75 KHz peak) subcarrier deviation. This level and impedance are compatible with the standard audio input for video tape recorders and studio monitors.

All circuits in the Baseband Processor are designed to operate from a power supply potential of +12 to +15 VDC (with +13.5 VDC being optimum). This potential is identical to the requirements of the RX-4200 Module Set, and the entire receiver may thus be operated from a single supply.

FABRICATION

The entire baseband processor assembly is constructed on a single, double-sided printed circuit board, etched from 1/16" thick, double-clad fiberglass-epoxy printed circuit laminate in accordance with the artwork shown on pages 8 - 12 and 8 - 13. The bulk of the components mount on the "groundplane" side of the board, which remains fully clad except for etched "islands" around those non-grounded component leads which must pass through the board to the trace side.

The etched and tin-plated board is drilled according to the template provided on page 8 - 14. Component mounting is per the layout drawings on pages 8 - 14 and 8 - 15. Grounded component leads should be soldered on both sides of the board, unless plated-through holes are employed. If wave-soldering is to be utilized, all components except C10, 15, 22, R13, 14 and 25 should be mounted, the board soldered, and then these trace-side components mounted manually. If volume production is anticipated, both plated-through holes and wave-soldering should be seriously considered.

The completed Baseband Processor should be connected to a well-regulated +13.5 VDC power supply for testing, and should draw on the order of 200 mA. The alignment and test procedures for the PLL Demodulator, AF Subcarrier Demodulators, and Video Processing Circuitry are listed on page 8 - 17. The photographs provided on page 8 - 19 will prove useful in determining proper video response, but the best test for any video system is to connect it to a monitor and observe video quality. In the case of video recovered from a geostationary satellite, subjective video quality improves discernibly for virtually every system modification which increases margin, providing the microwave experimenter with countless, justified opportunities for priding himself on his accomplishments!

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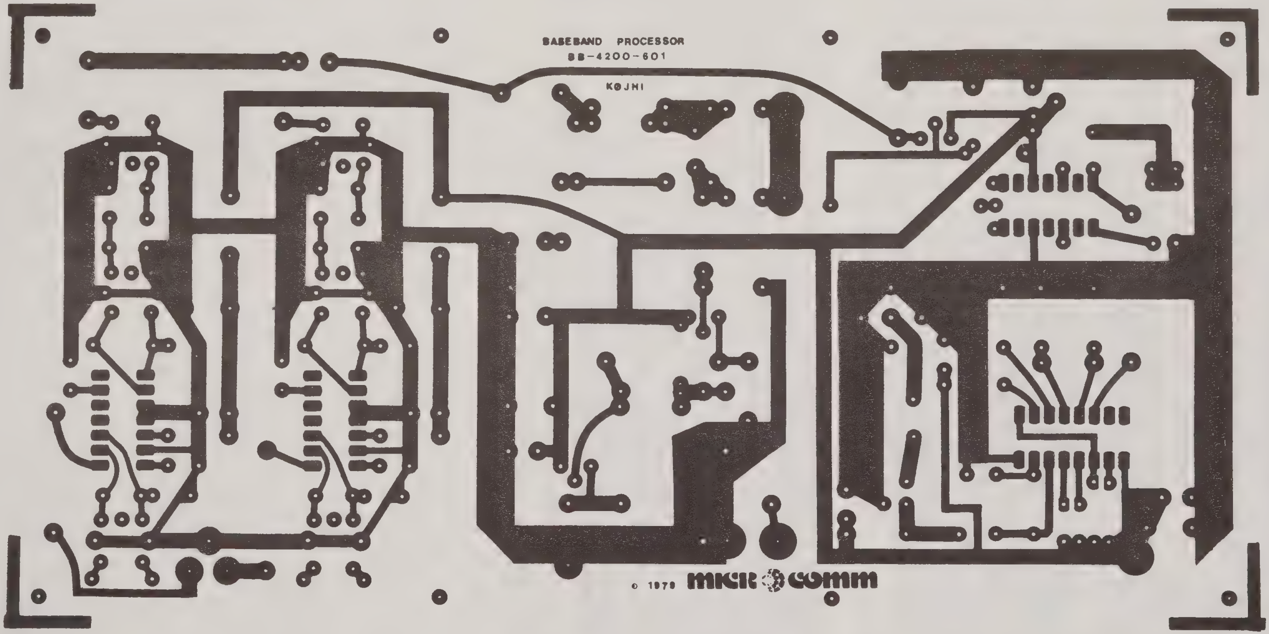

PC Positive (Black = Copper)

TRACE SIDE

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BASEBAND PROCESSOR
Printed Circuit Artwork

SIZE	CODE IDENT NO.	DRAWING NO.
		BB-4200-601
SCALE 1 : 1		SHEET 1 OF 2

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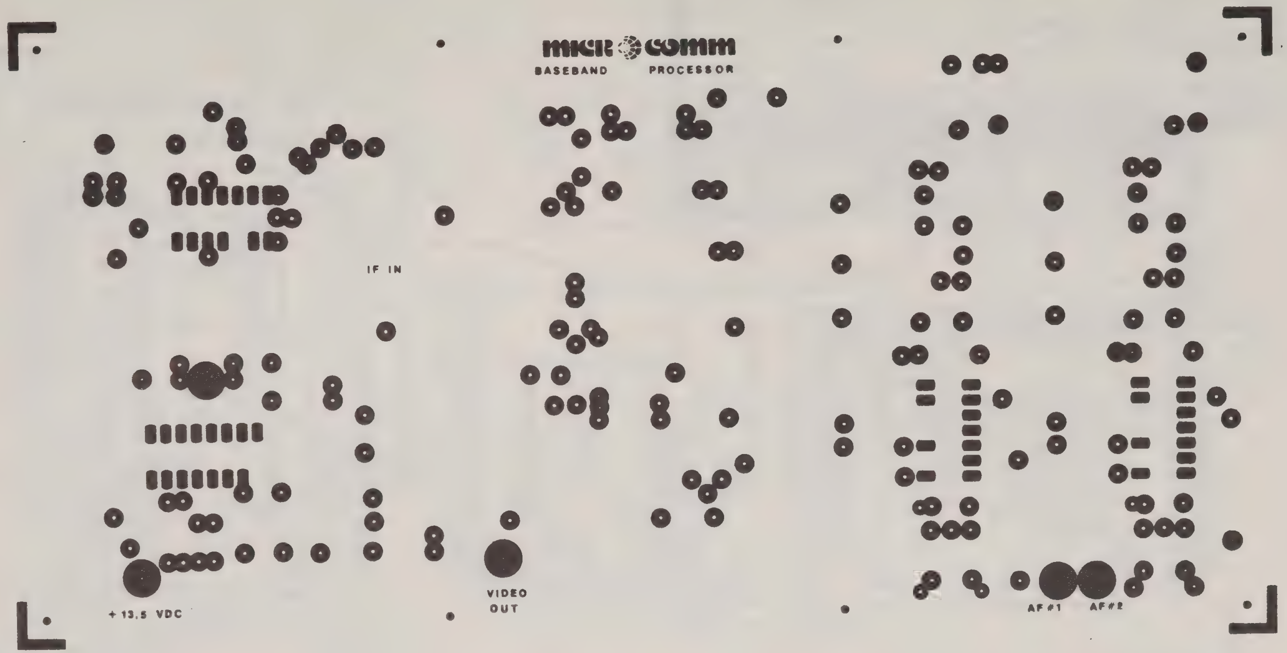

PC Negative (White = Copper)

GROUNDPLANE SIDE

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BASEBAND PROCESSOR
Printed Circuit Artwork

SIZE	CODE IDENT NO.	DRAWING NO.
		BB-4200-601
SCALE 1 : 1		SHEET 2 OF 2

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\# 27, 9 PLCS
\# 42, 20 PLCS
\# 65, 285 PLCS

(TRACE SIDE)

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BASEBAND PROCESSOR DRILLING INSTRUCTIONS

SIZE	CODE IDENT NO.	DRAWING NO. BB-4200-701
SCALE		SHEET 1 OF 1

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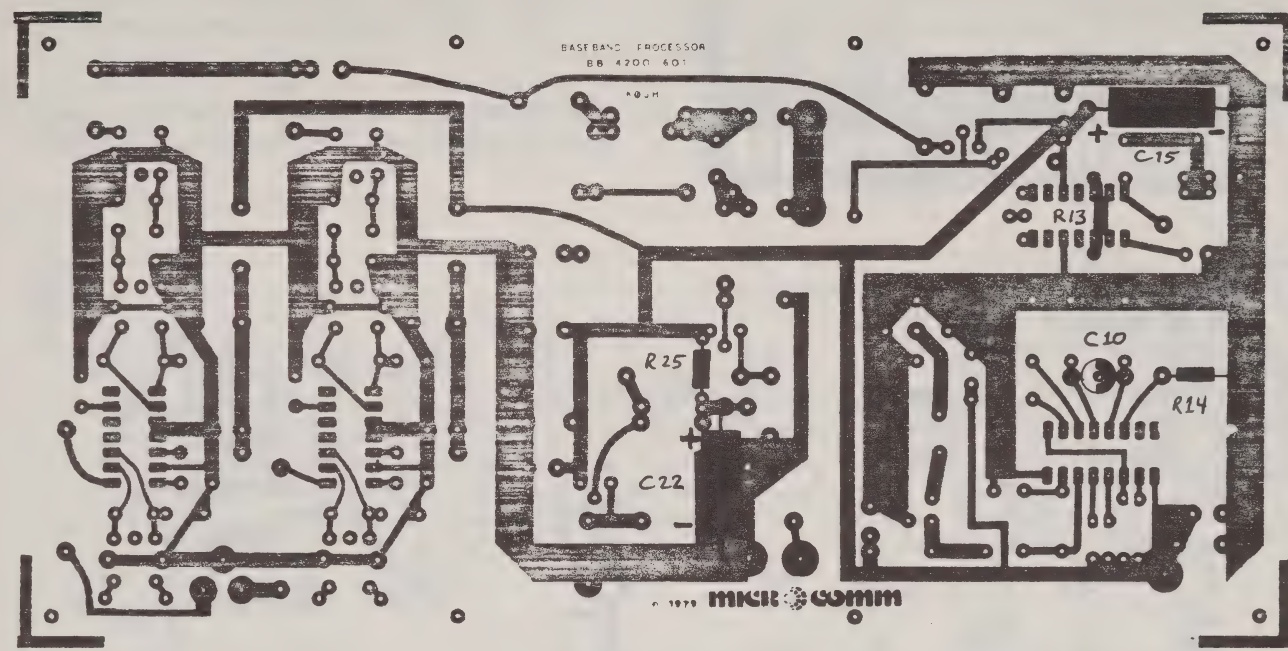
LTR	DESCRIPTION	DATE	APPROVED



COMPONENTS MOUNTED ON TRACE SIDE OF PRINTED CIRCUIT BB-4200-601

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Baseband Processor - Assembly Drawing

SIZE	CODE IDENT NO.	DRAWING NO.
		BB-4200-801
SCALE 1:1		SHEET 1 OF 2

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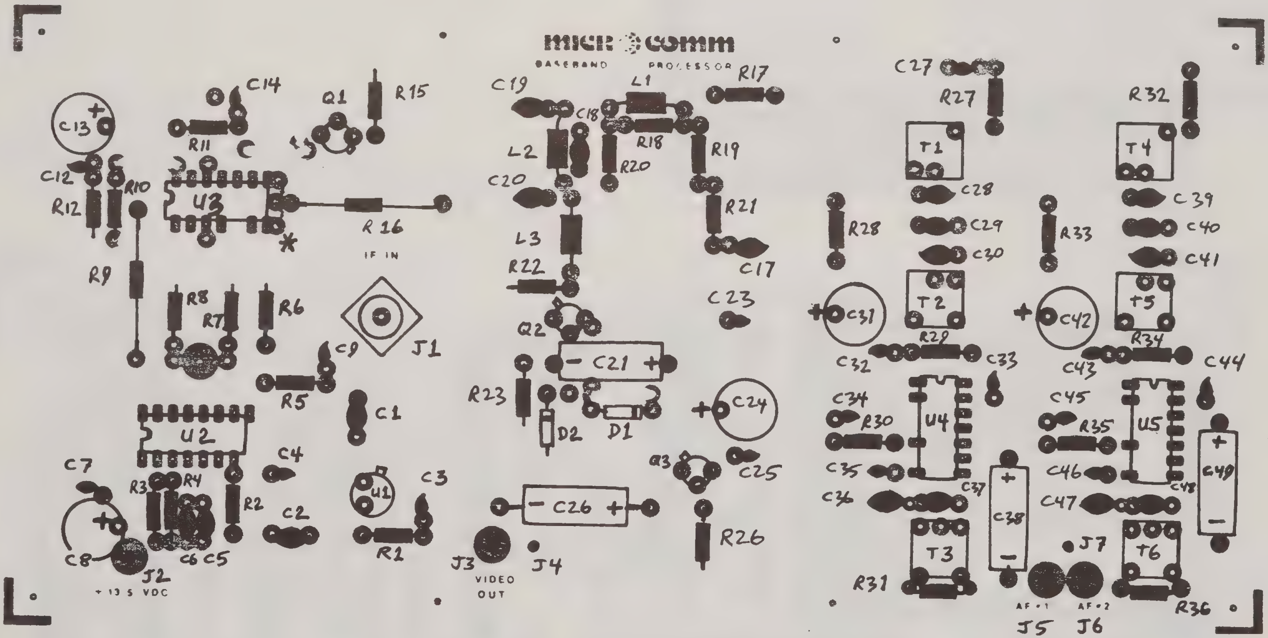
LTR	DESCRIPTION	DATE	APPROVED
A	ADD R9A	02/08/79	SL



COMPONENTS MOUNTED ON GROUNDPLANE SIDE OF PRINTED CIRCUIT BOARD BB-4200-601

* Jumper between output of U3 and C16.
Install in upper position for standard video;
in lower position for inverted video.

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Baseband Processor - Assembly Drawing

SIZE	CODE IDENT NO.	DRAWING NO.
		BB-4200-801
SCALE 1 : 1		SHEET 2 OF 2

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LTR	DESCRIPTION	DATE	APPROVED

PLL ALIGNMENT AND TEST

1. Connect a 50-ohm load to J1; couple U2 pin 9 to a digital frequency counter via a high-frequency 10:1 probe.
2. Adjust C10 for an indicated VCO frequency of 70 MHz (or other desired operating frequency).
3. Remove load from J1. Attach VHF Signal Generator to J1. Set generator to frequency of VCO (step 2 above).
4. Adjust output of signal generator to CW, at -20 dBm (20 mV/50 ohms).
5. Tune signal generator to VCO frequency plus and minus 10 MHz. Verify on frequency counter that PLL tracks.

AUDIO DEMODULATOR ALIGNMENT

1. Remove signal generator from J1 and re-install load. Remove counter from U2 pin 9.
2. Adjust FM Signal Generator for 6.8 MHz carrier, 1 kHz sine-wave modulation, and 75 kHz peak deviation.
3. Apply -10 dBm signal level from FM signal generator to junction of C27, R27, and R32.
4. Connect an audio oscilloscope to J5. Also connect a 600 ohm resistor between J5 and J7.
5. Adjust T1, T2 and T3 alternately for maximum undistorted sinusoidal output, as indicated on oscilloscope.
6. Decrease output amplitude of FM generator by 10 dB. Repeat the above adjustment. Output amplitude indicated on oscilloscope should be on the order of 1 mV peak-to-peak.
7. Move oscilloscope probe and 600 ohm resistor from J5 to J6. Reset the carrier frequency of the FM signal generator to 6.2 MHz.
8. Repeat the above adjustments for second audio subcarrier demodulator, tuning T4, T5, and T6.

VIDEO PROCESSOR TEST

1. Apply a downconverted DOMSAT composite signal to J1, using Microcomm RX-4200 Module Set or equivalent.
2. View signal at emitter of Q1 with an oscilloscope and 10:1 high-frequency probe. Signal should show video and energy dispersal waveforms, as shown in accompanying photograph.
3. View Video Output at J3 on oscilloscope, with a 75 ohm resistor connected from J3 to J4. Output amplitude should be 1 volt pk-pk. Signal should resemble the accompanying photograph.
4. Apply video and selected audio output from baseband processor to monitor, modulator or videotape recorder for display.

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BASEBAND PROCESSOR
Alignment and Test Instruction

SIZE	CODE IDENT NO.	DRAWING NO.
		BB-4200-901
SCALE		SHEET 1 OF 2

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REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED

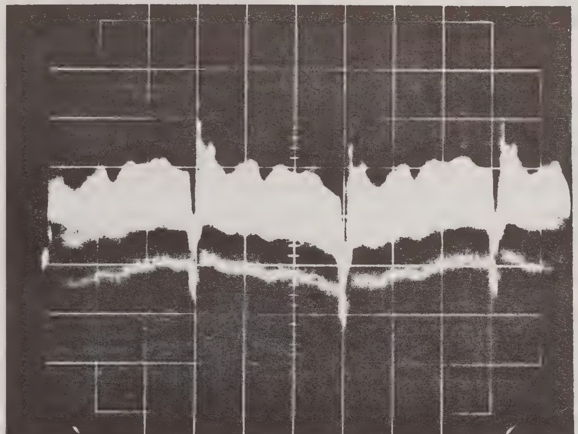

PHOTO A - Q1 output (see Video Processor Test Instruction 2 on BB-4200-901, Sheet 1 of 2).

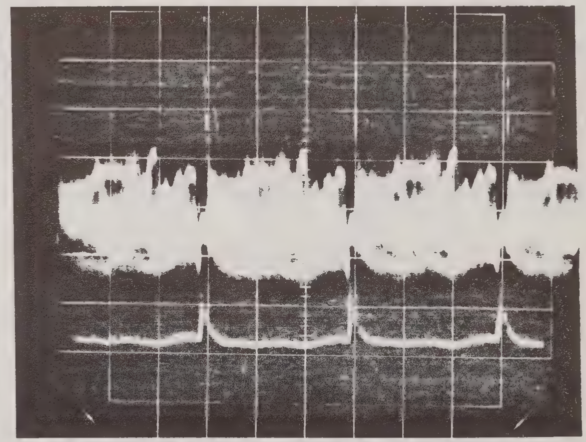

PHOTO B - J3 output (see Video Processor Test Instruction 3 on BB-4200-901, Sheet 1 of 2).

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BASEBAND PROCESSOR
Alignment and Test Instructions

SIZE	CODE IDENT NO.	DRAWING NO.
		BB-4200-901
SCALE		SHEET 2 OF 2

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MICROCOMM
Application Note #3
One Dollar

A "Vidiot's" Guide To Microwave TV Links

An explosion in high-frequency TV transmission has created many opportunities and much confusion for the microwave experimenter. Baffled by ITFS, MDS, and TVRO receivers? Read on for the facts.

MILLIONS of Americans now enjoy an exciting new source of informative, entertaining television programming. Most viewers pay premium prices to have limited programming piped into their homes by cable television systems. But a growing number of intrepid microwave experimenters are using home-brew systems to receive a wider variety of first-run movies, sporting events, and educational programs (see, "Are signals free, or is there a fee?").

It has been clearly demonstrated, in recent years, that the distribution of television programs over wide geographical areas can be accomplished most efficiently by use of microwave links, either terrestrial or satellite based. Not only is the available spectrum width a consideration in selecting microwave frequencies over other portions of the radio spectrum, but in many cases, the cost per channel of a microwave distribution system is significantly less than cable distribution. For this reason, the microwave spectrum is filled with thousands of video signals whose reception is of interest to microwave experimenters.

Instructional TV links classrooms

Instructional television fixed service (ITFS) provides 31 channels of 6-MHz-wide intercarrier TV for educational purposes. Channel format is a standard NTSC-compatible color transmission, identical to VHF and UHF TV broadcasts.

The ITFS band extends from 2.50 to 2.69 GHz. Reception generally involves linear heterodyne conversion of a given 6-MHz-wide channel into a VHF TV receiver. A typical ITFS system includes up to four simultaneous channels of programming, broadcast from a common transmit antenna on four alternating (rather than adjacent) channels (Fig. 1). The frequency scheme is such that the four channels may be heterodyned against a single local oscillator (in this case 2422 MHz) and downconverted directly to TV channels 7, 9, 11, and 13.

The output of the downconverter feeds into a VHF TV cable distribution system so that multiple receiving points (classrooms) may individually select from the four available programs. Such distribution demands high frequency stability of the downconverted signals; thus ITFS downconverters employ high-stability crystal-controlled local oscillators.

The output power of an ITFS transmitter is typically 10 W per channel, and the transmit antenna is generally omnidirectional, with about +10-dBi gain. Thus, the effective isotropic radiated power (EIRP) is about +50 dBm.

H. Paul Shuch, Chief Engineer, Microcomm, 14908 Sandy Lane, San Jose, CA 95124.

A state-of-the-art ITFS downconverter exhibits a noise figure of 3 dB or less. At a 6-MHz bandwidth, this makes the single-channel threshold sensitivity of the receiver about −130 dBm. Since AM vestigal sideband video requires about 30-dB carrier-to-noise ratio for snow-free reception, the signal level present at the input to the downconverter must exceed −73 dBm. Given +50-dBm EIRP from the transmitter, the sum of path loss and receive antenna gain must be greater than −123 dB.

At 2.6 GHz, the gain of a properly illuminated 0.6-m parabolic antenna is close to +22 dBi. With such an antenna, the maximum permissible path loss is −145 dB, which corresponds to a transmission distance of roughly 160 km (which exceeds line-of-sight over most paths). Since this calculation assumes an unobstructed line-of-sight path, it is clear that with today's receiver technology the distance over which ITFS signals can be reliably received is restricted primarily by antenna height and the curvature of the earth.

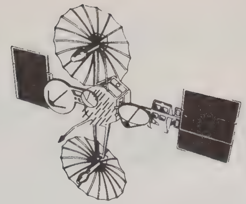
A high-performance ITFS downconverter (Fig. 2) can be built for about $700. The preamplifiers are usually single-stage bipolar units that exhibit 10-dB gain per stage at a cascade noise figure of 3 dB or less. The bandpass filter can be implemented in edge-coupled microstrip, and should exhibit minimal passband insertion loss while affording at least 20-dB image rejection. A typical balanced mixer employs a matched pair of Schottky-barrier diodes and a microstripline coupling structure, and exhibits not more than 7-dB conversion loss with at least 20 dB of LO-to-RF port isolation. The IF amplifier must be sufficiently broadband to allow the use of any desired VHF TV channel as an output; thus, untuned low-noise bipolar transistors are generally used. The gain of the IF amplifier must be sufficiently high to mask the losses in the distribution system. The cost of these components combined on a board is in the neighborhood of $300.

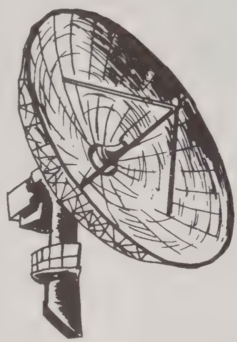
The LO chain presents a major design challenge, because it must provide adequate injection to drive the balanced mixer (+5 to +7 dBm), while exhibiting high spectral purity and reasonable thermal stability. These considerations dictate a high crystal frequency for the oscillator stage, and well-filtered low-order multiplier stages, as shown in Fig. 2. This high-quality LO chain might cost an additional $300.

MDS distributes TV entertainment

The multipoint distribution service (MDS) provides two common-carrier channels for the distribution of video programming. Unlike ITFS, the MDS allocation was established to distribute entertainment programming. MDS transmissions are carried on one of two channels: channel A, from 2150 to 2156 MHz, and channel B, from 2156

to 2162 MHz. Currently, only one of these two channels is allocated for any given geographical area. Like ITFS, the MDS signal is intercarrier, vestigal-sideband video with FM audio, and NTSC color—but with a twist. The transmission passband is inverted, resulting in lower vestigal-sideband video, with the video carrier 1.25 MHz below the upper band edge, and an audio carrier 4.5 MHz below the video carrier!





This is the opposite of the transmission spectrum used for standard TV broadcasts, but the video can be readily displayed on a VHF or UHF TV by inverting the signal in the downconversion process. This inversion is accomplished by injecting a local oscillator signal into the mixer that is above rather than below the incoming carrier's frequency by an amount equal to the desired IF frequency.

Aside from the requirement for high-side LO injection, the block diagram for an MDS downconverter can look like that of the ITFS converter in Fig. 2. To clarify the frequency inversion requirements, Fig. 3 lists the input and output frequencies for an MDS converter using channels 8 and 7 to recover channels A and B. Note that a single LO frequency of 2336 MHz causes the sound and video carriers of the two incoming channels to align with the corresponding frequencies of the respective IF channels.

The selection of channels 8 and 7 is not arbitrary. A good rule-of-thumb for adequate image rejection is to select an IF equal to about one-tenth of the input frequency. Therefore, the high VHF channels make a better IF choice for an MDS downconverter than either the low VHF or UHF channels.

Downconversion of ITFS signals demands a highly stable LO. This is not the case in MDS reception, where a single program channel is being recovered at a single location. Thus considerable cost savings can be realized with a downconverter that incorporates a free-running oscillator as its LO, rather than the complex and costly oscillator/multiplier/filter chains typical of ITFS converters. In fact, many experimenters have received entirely satisfactory MDS signals by injecting the output of a free-running microwave signal generator, tuned to the 2.3-GHz region, into the LO port of a balanced mixer. Because laboratory signal generators tend to be large and heavy, a better approach would be to develop a small, solid-state voltage-controlled oscillator (VCO) that could be remotely tuned by varying an applied DC potential.

In order to hold costs down, most commerical MDS downconversion modules exhibit fairly high noise figure, minimal input filtering, and conversion gain which may prove inadequate in some commercial applications. If improved sensitivity or selectivity is required, it is always possible to add single-stage preamplifiers, bandpass filters, or IF post-amplifiers to the basic downconverter, in modular fashion. In this way, the performance of an MDS downconverter may easily be tailored to particular needs and budgets.

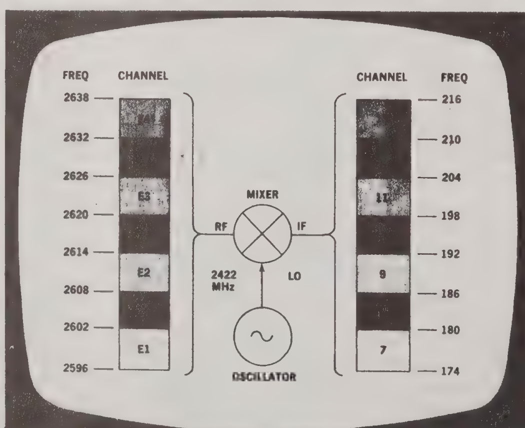
Like ITFS transmitters, most MDS systems use 10-W transmitters that feed into omnidirectional antennas with approximately +10-dBi gain. A path analysis determines the required antenna size and receiver sensitivity to achieve the desired +30-dB carrier-to-noise ratio.

Space repeaters are a reality

The "great repeater in the sky" has become a reality in recent years. A series of North American domestic communications satellites (domsats) now distribute network TV programs, first-run movies, sporting events, nightclub entertainment, and the like to TV stations, cable TV companies, and in some cases, private viewers. Many would-be users of these satellite links have been discouraged by the rather high cost of commercial receiving equipment (often several tens of thousands of dollars), and by the dearth of authoritive information on the signals and their characteristics. Although the advanced microwave experimenter can do much to reduce the costs of a television receive-only terminal (TVRO) by constructing much of the receive equipment, an undertaking of this complexity is still considerably more costly and time consuming than assembling a station for recovery of terrestrial microwave video sources.

The major difficulties to be overcome in TVRO design and construction include low signal level, spectral dispersion, and video formatting. The amplitude of a signal recovered on the

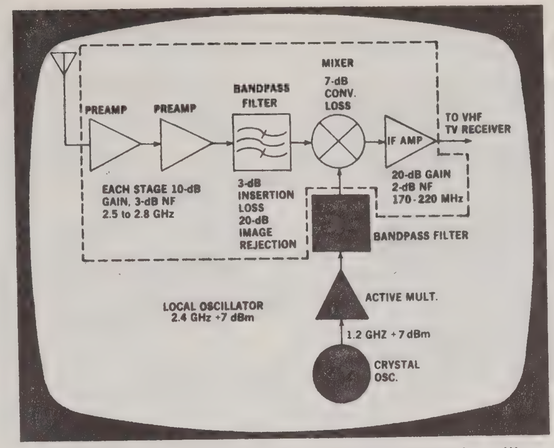
(continued on p. 43)



*1. **The typical ITFS downconversion frequency scheme** puts the microwave channels into VHF TV channels.*

ground is inversely proportional to both the transmission distance and the frequency. Since domsats are situated above the equator in geostationary orbit (35,000-km high), path attenuation is very high. The 4-GHz downlink frequency also adds to path loss.

The existing domsats employ wideband frequency modulation for video and audio transmission. Since standard broadcast TV employs an amplitude-modulated, vestigal-sideband video signal of relatively narrow bandwidth, it is evident that a compatibility problem exists. An incoming satellite link cannot simply be heterodyned against a microwave local oscillator, downconverted to VHF, and displayed on a standard TV receiver. Rather, it is necessary to demodulate the video and audio signals separately from the wideband FM downlink composite, process each, and then reconstruct the intercarrier, vestigal-sideband RF composite for display on a TV receiver.



2. An ITFS downconverter *employs a high crystal oscillator frequency to provide adequate stability.*

Satellites handle 12 or 24 channels

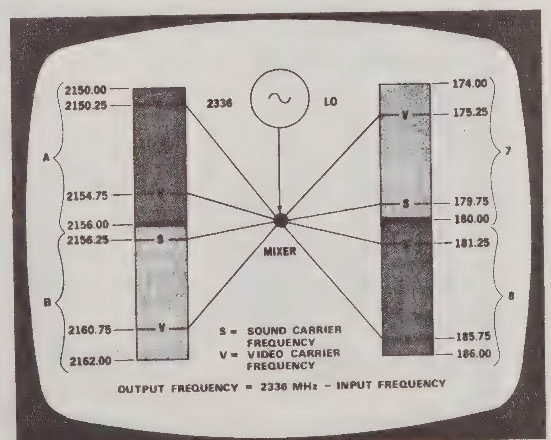
The band that is currently being used for domsat downlinks extends from 3.7 to 4.2 GHz. Each satellite accommodates either 12 or 24 channels, each 40-MHz wide. The 24-transponder satellites accomplish the trick by allocating two overlapping sets of twelve channels to mutually orthogonal linear transmission polarizations. In order to allow a guard band between channels, only 36 MHz of each channel is actually used. The transmitted signal consists of a 4.5-MHz-wide NTSC composite video/sync/color burst signal, plus a 6.2 or 6.8-MHz subcarrier which is frequency modulated with the program audio. These two elements are then frequency modulated onto the ultimate transmission carrier with a peak deviation of 10.25 MHz. The composite is further "dithered" ±750 kHz at a 30-Hz rate as an interference-reducing technique. The resulting deviation ratio equals the peak deviation divided by the maximum modulating frequency, or roughly 1.5.

The bandwidth occupied by an emission is defined as that spectrum containing 99 percent of the total radiated power. For wideband FM, this equals approximately twice the highest modulating frequency plus twice the peak deviation. The bandwidth of domsat video transmissions is thus roughly 34 MHz at the 20-dB points, which is entirely compatible with the 36-MHz channel allocation.

All of which is to say that a receiver for TVRO use must detect a 34-MHz wide FM signal, demodulate the video, and extract and demodulate the audio subcarrier. If the incoming signal were simply heterodyned down into the input of a VHF or UHF TV, the result would be to spread unintelligible FM sidebands across six adjacent channels.

The signal level available from a geostationary satellite, unlike that from terrestrial microwave sources, is extremely weak, but quite predictable. This is because the transmitter power and antenna gain of these satellites are well defined, and the distance between the satellite and all receiving stations is essentially the same. Video transponders aboard the current generation of domsats output a relatively high EIRP (in the order of +65 dBm). Given a free-space path loss in the order of −196 dB, the signal level available to the receive antenna will be about −131 dBm. But this signal is spread out across the 34-MHz channel width, resulting in an average spectral density at the receive antenna of roughly −206 dBm/Hz. Since the thermal-noise threshold of a "perfect" receiver at earth temperature is −174 dBm/Hz, it is evident that the receive antenna must exhibit about +32-dBi gain, just to achieve a unity signal-to-noise ratio into a noiseless receiver!

In reality, the receiver itself contributes some thermal noise to the system, as does the warm (relative to absolute zero temperature) surface of the receive antenna. Then too, intelligible video generally requires that the carrier-to-noise ratio exceed about +8 dB (commercial broadcast quality requires +10 dB or greater). Thus, one can expect a 4.5-m parabolic reflector to be the minimum antenna size that will yield noise-free images with a practical receiver. Some experimenters have achieved commercial-quality reception with antennas as small as 3 m, by using the most advanced (and costly) receive electronics available. The same experimenters have reported that video signals recovered with small (2 to 2.5 m) dishes have been "'distinguishable, but marginal." In terms of cost ef-

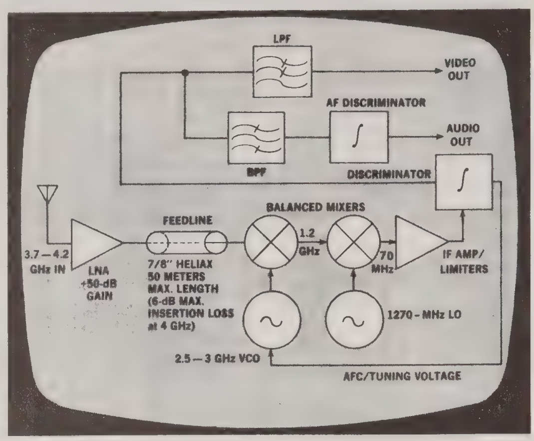


3. The spectrum of an MDS signal *is inverted, requiring the LO to be above the incoming carrier's frequency.*

(continued on p. 45)

fectiveness, it seems practical at this time to plan a system around a fairly large (4-to-4.5-m) antenna, in conjunction with readily available, less exotic receive electronics.

Given a properly illuminated 4.5-m receive antenna, it is possible to receive noise-free images with an overall receiver noise temperature of 290°K (a noise figure of 3 dB). Such receiver performance is obtainable today from ion-implanted bipolar transistors that are available at relatively low cost. Should you require the higher carrier-to-noise ratio associated with broadcast-quality installations, or should you desire comparable performance with a smaller antenna, the use of a delicate GaAs FET amplifier would be indicated.



***4. This domsat receiver** uses a costly high-gain amplifier at the antenna to mask transmission line loss.*

TVRO design relies on low-noise amplifiers

The prevalent approach to TVRO design involves the use of a high-gain (+50 dB typical), low-noise amplifier (LNA) located directly at the antenna feed, connected via a relatively long transmission line to a dual-conversion FM receiver (see Fig. 4). The high gain of the LNA masks the considerable insertion loss of the transmission line, as well as the high input noise figure (typically 15 dB) of the 4-GHz receivers that are currently in use.

Since the LNA represents the major cost item in a TVRO terminal, anything that can be done to reduce the gain requirement (and hence the number of 4-GHz preamp stages) has a significant impact on system cost. Improvements can be realized by either lowering the noise figure of the basic receiver, or significantly reducing feedline losses. Attempts have been made to do both in assembled private terminals.

One major drawback in the receiver of Fig. 4 is the lack of IF gain between the two conversion stages. It is possible to reduce the noise figure of the basic receiver by at least 5 dB, simply by inserting a low-noise 1.2-GHz preamplifier immediately after the first downconversion mixer. In fact, the selection of 1.2 GHz as a first IF is fortuitous, in that many of the readily available receive modules for the amateur 23-cm (1.3 GHz) band can be employed. L-band preamplifiers that offer low noise figure (2 dB typical) and high gain (15 dB or more) have been available for some time, as have bandpass filters, crystal-controlled local oscillators, and balanced mixers for the second downconversion. By employing these modules after the first mixer in a system such as that of Fig. 4, the noise figure of the basic receiver can be reduced significantly.

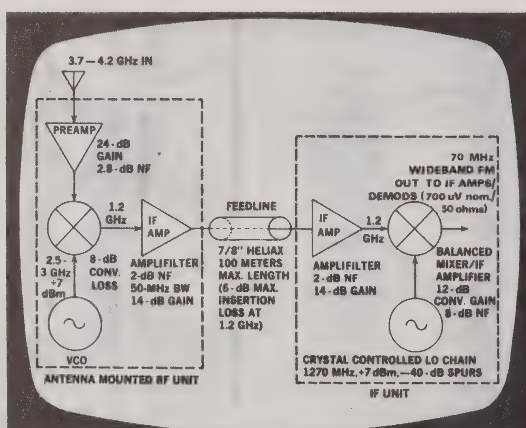
Minimize line loss

The next step in receiver optimization would be to minimize the effects of transmission line loss, and this can be accomplished by performing the first heterodyne downconversion directly at the antenna feedpoint. The insertion loss of any length of high-quality coaxial cable is approximately half as great at 1.2 GHz as it is at 4 GHz. Therefore, simply moving the first mixer and local oscillator to the antenna cuts feedline losses in half. But the presence of an IF amplifier before the feedline masks its losses almost entirely, making it extremely desirable to mount at least one 1.2-GHz amplifier at the antenna as well. Since 1.2-GHz gain stages are less costly than 4-GHz amplifiers, this seems an ideal way to mask feedline losses economically.

A receiver built along these lines includes a remote downconverter, and IF and demodulator units, as shown in Fig. 5. This system permits the gain and the cost of the LNA to be reduced to half, while achieving a system sensitivity on a par with the receiver of Fig. 4. Circuit modules for this receiver would cost about $1700 in single quantities.

High-power satellites are coming

Considerable work is being done to develop and deploy high-power satellites to provide quality video downlinks in the 12-GHz region. One experimental satellite (CTS) is currently serving the North American continent with signals so intense that recovery is possible with simple ground stations that cost perhaps one-tenth the amount being spent to receive C-band domsat signals. Another high-power satellite is currently being tested over Japan and Okinawa, with several experimental European spacecraft pending. But the costs of 12-GHz spacecraft hardware are still ex-



***5. An improved domsat receiver** performs the first downconversion directly at the antenna feedpoint.*

(concluded on next page)

tremely high, so that for the forseeable future, commercial satellite TV programming will probably continue to be distributed in the 4-GHz region.

Introduction of high-power satellites could change the method of broadcast of TV signals. With all program channels flowing from a satellite's transponders, country-wide viewers could aim their rooftop antennas at the same point in the sky. That would be a super network!••

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15. "MDS - The Hidden Service," CATJ, p. 14, (April, 1979).

Are signals free, or is there a fee?

In the US, a strong tradition supports the belief that any signals radiated are there for all to share, at no cost to the user. On a recent television news broadcast, one well-known educator loosely described microwave TV signals as "free photons falling from the sky."

However, to paraphrase that witty philosopher Will Rogers, "there ain't no free photons." The video signals described in this article are not from broadcast, but from common-carrier services. As such, the programming falls under the protection of the Communications Act of 1934. It is conceivable that unauthorized interception may be interpreted by the courts as an invasion of privacy by eavesdropping on private communications.

Fortunately, it is relatively easy for the technically inclined to obtain licensing for an experimental receiving station, and most carriers distributing television programming will authorize you to intercept their signals for personal, non-commercial use. Many charge a small monthly fee based upon the number of viewers, or households served. In any event, the experimenter is urged to give the legal aspects of common-carrier interception careful thought before assembling a station.

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How to handle amplifier/antenna tradeoffs

Factors that determine the signal-to-noise ratio achieved by a television receive-only (TVRO) earth station include antenna gain and receiver noise temperature. Recent advances in low-noise amplifier (LNA) technology have invalidated many of the traditional rules-of-thumb for system design. H. Paul Shuch, a prolific writer on the subject of TVRO terminals, now offers a paper that explores the cost and performance criteria pertinent to the selection of optimum antenna gain and LNA noise temperature for private TVRO terminals.

After reviewing input figure of merit and comparative costs of LNAs and antennas (both home-brew and purchased), the paper analyzes cost tradeoffs. Shuch makes personal recommendations, and concludes: "It is feasible to construct a very satisfactory TVRO terminal for about $3000. With today's satellites, the system affords the private viewer a wealth of programming for the money."

The six-page Microcomm application note No. 4 (April 12, 1979) is available for $1.00 plus a stamped, self-addressed envelope. Microcomm, 14908 Sandy Lane, San Jose, CA 95124

H. Paul Shuch, formerly an ECM Reconnaissance Receiver Designer for ITEK's Applied Technology Division, for several years taught electronics courses at West Valley College, Saratoga, CA, and has served as a Senior Engineering Instructor for Lockheed Missiles and Space Company, Sunnyvale, CA, specializing in RF, Microwave Systems. In 1975 he founded MICROCOMM, a small company devoted to the design, development, and manufacture of microwave communications equipment. The downconverter presented here represent one of their major efforts. He is currently on the faculty of San Jose City College, San Jose, CA. He is widely published in the areas of microwave circuit and system design, fabrication, and application. His articles in various electronics periodicals number over twenty in the past three years. He has also lectured around the US, and is a regular speaker at the Annual West Coast UHF Conference. Avocationally, he is a leading UHF microwave experimenter, holding an extra-class amateur radio license. In that connection, he has explored tropospheric scatter and meteor scatter propagation techniques, utilized the lunar surface as a passive reflector to return VHF signals to earth, and been instrumental in the amateur communications satellite program. His work with the radio Amateur Satellite Corporation (AMSAT) and Project OSCAR (Orbiting Satellite Carrying Amateur Radio) resulted in his participation in the dedication of the National Air and Space Museum, Washington, DC.

ANTENNA/LNA TRADEOFF ANALYSIS FOR C-BAND VIDEO TERMINALS

Microcomm Application Note #4
April 12, 1979 / Rev. Aug '79
One Dollar

by H. Paul Shuch
Chief Engineer, Microcomm
14908 Sandy Lane
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Abstract: Factors determining the signal-to-noise ratio achieved by a Television Receive Only (TVRO) earth station include antenna gain and receiver noise temperature. Recent advances in Low Noise Amplifier (LNA) technology have invalidated many of the traditional "rules of thumb" in system design. This paper explores the cost and performance criteria pertinent to selecting optimum antenna gain and LNA noise temperature for private TVRO terminals.

Introduction

In an earlier Application Note[1] I made the observation that for optimum cost effectiveness in TVRO terminal design, the private experimenter should consider the use of a bipolar transistor LNA in conjunction with a large (15' Diameter) parabolic antenna. These suggestions were based upon the then high cost and limited reliability history of Gallium-Arsenide Field Effect Transistors (GaAs FETs) as C-band LNAs.

The recent proliferation of lower cost, higher performance and presumably higher reliability GaAs FET LNAs has challenged the validity of my original assertion. Clearly, an analytical trade-off analysis is indicated, and if current technological trends continue, will need to be repeated every few months for the forseeable future.

Before surveying the state of the art in antennas and LNAs, it will be helpful to review G/T, the figure of merit for predicting TVRO performance.

Input Figure of Merit

The ratio G to T (Antenna Gain to System Noise Temperature) is a universally accepted figure of merit for receive terminal performance. Although the fraction G/T involves a unitless ratio, in practice what is usually measured or specified is 10 log (G/T), expressed in decibels (dB). By converting both antenna gain and noise temperature to dB, the figure of merit may be found by subtraction rather than division. G/T thus equates to (10 log G) - (10 log T_{eq}), where the first term represents antenna gain in dBi (decibels over an isotropic radiator), and the second term represents the equivalent noise temperature of the entire system, in degrees Kelvin.

System noise temperature for a cascade is typically found by adding the thermal noise contributions of the LNA, the Antenna, and the following Receiver stages. It is common practice to assume that system noise temperature is essentially equal to that of the LNA. However, this simplification may add considerable error to the G/T calculation, especially if LNA gain is insufficient to completely mask second-stage noise contribution [2], or if a low-efficiency antenna feed is used.

In most practical feed designs, the thermal noise contribution of the antenna system can be held to 10° K or less. As for second stage noise contribution, it is frequently (but not always) completely masked by the LNA.

Second-stage noise contribution is found by dividing the second-stage noise temperature (in degrees Kelvin) by the LNA gain (expressed as a power ratio). In a typical

commercial TVRO terminal, second stage noise figure (actually the sum of receiver noise figure and the insertion loss of the feedline which precedes the receiver) may total on the order of 16 dB. This represents an 11,000 ^{o} K second-stage noise temperature. A commercial LNA may exhibit on the order of 50 dB gain, a power ratio of 1×10^5 . Under these conditions, the receiver and feedline together contribute on the order of 0.1 ^{o} K to the system's equivalent noise temperature, and may readily be ignored.

Of course, if a lower gain LNA is employed, it may be necessary to consider second-stage noise contribution in determining system T_{eq} . In the above example, reducing LNA gain to 30 dB increases second-stage noise contribution to 11 ^{o} K, which may significantly impact system performance.

Given an LNA with sufficient gain to effectively mask the second stage thermal noise contribution, it is convenient to assume that system noise temperature will exceed LNA noise temperature by 10 degrees Kelvin. This is the usual manner of approximating T_{eq} for system G/T computations.

How Much is Enough?

Obvisusly, the higher the G/T of any earth station (that is, the more antenna gain per unit of system thermal noise), the greater will be the signal-to-noise ratio received for a given downlink. Assuming the +35 dBw illumination contour typical of most North American Domestic Communication Satellites (DOMSATs), it is generally felt that a system G/T of +18 dB is sufficient to recover noise-free (if not Broadcast Quality) video.

Table A lists several combinations of antenna size and LNA noise figure which will each yield a system G/T within one decibel of this target at 4 GHz. It would appear that any of the combinations listed would prove adequate for use in private TVRO terminals, in the absense of other system constraints.

TABLE A

Antenna/LNA Combinations Yielding System G/T of roughly +18 dB.

Antenna		LNA	
Dia. (ft)	Gain (dBi)	NF (dB)	Teq (^{o} K)
6	35	0.7	50
8	37.5	1.3	100
10	39.5	1.8	150
12	41	2.0	180
15	43	2.6	250

Costs to Build and to Buy

It can be seen from Table A that an 18 dB G/T from a 6' terminal would require an LNA exhibiting a noise temperature on the order of 50 ^{o} K. Since such performance is beyond the current state of the art for uncooled GaAs FETs, it would appear that earth stations using such small antennas would require either cryogenic or parametric preamplifiers to achieve adequate performance in a +35 dBw illumination contour. Both amplifier types are quite costly, either to purchase or to construct, which suggests that the 6' TVRO terminal may well be impractical at today's level of technology. However, all of the other LNA noise temperature options listed are readily achievable with off-the-shelf GaAs FET amplifiers from various vendors. Furthermore, amplifiers in the 100 to 250 ^{o} K region

have been successfully home-built by a number of advanced microwave experimenters, at considerable cost savings (see Table B).

Parabolic reflectors with feeds have for some years been offered in a variety of sizes for terrestrial communications applications, and these same antennas serve quite well in TVRO systems when aimed skyward. Table C lists the prices charged for several such antennas by one well-established supplier, as well as the materials costs which several microwave experimenters have encountered in constructing home-built antennas.

In deliberating the make-or-buy decision, the home TVRO constructor is cautioned not to underestimate the magnitude and complexity of such a homebrew project. Although materials costs for home-built antennas are quite low, I have known very talented experimenters who have invested every afternoon and weekend hour for months on end, only to find the finished structure deficient in gain by several dB. As for LNA construction, the component costs can escalate all out of proportion the minute an improper soldering operation or careless test procedure wipes out a whole handful of $100-plus transistors. And I speak from personal experience here !

On the other hand, there is no joy comparable to the satisfaction felt when a homebrew antenna or LNA finally yields viewable pictures. Those who relish technical challenge should find homebrewing their own TVRO terminal immensely rewarding.

TABLE B

Representative LNA costs

T_{eq} (Deg. K)	$ Commercial	$ Home-Built
50	5K	3K
100	2.8K	1.9K
150	1.6K	1.3K
180	1.4K	800
250	1.3K	400

Commercial prices (except for the 50^{o} K LNA) are based upon standard 50 dB gain models available from Scientific Communications Inc., 3425 Kingsley Road, Garland TX 75041. See text.

TABLE C

Representative Antenna Costs

Diameter (feet)	$ Commercial	$ Home-Built
6	1.4K	100
8	1.9K	150
10	2.5K	300
12	4.9K	500
15	10.6K	800

Commercial prices are based upon standard microwave communications antennas available from Andrew Corp., 10500 W. 153rd St., Orland Park IL 60462. See text.

Cost Tradeoff Analysis

OK, so you've made your decision to build or to buy, as the case may be. How large an antenna, and how quiet a receiver, will you need to achieve adequate reception at a minimum of expense? That question is answered in part, for purchased and home-built systems, in figures 1 and 2 respectively. Each figure shows the cost for antennas of various sizes, compatable LNAs, and total cost for these two key items.

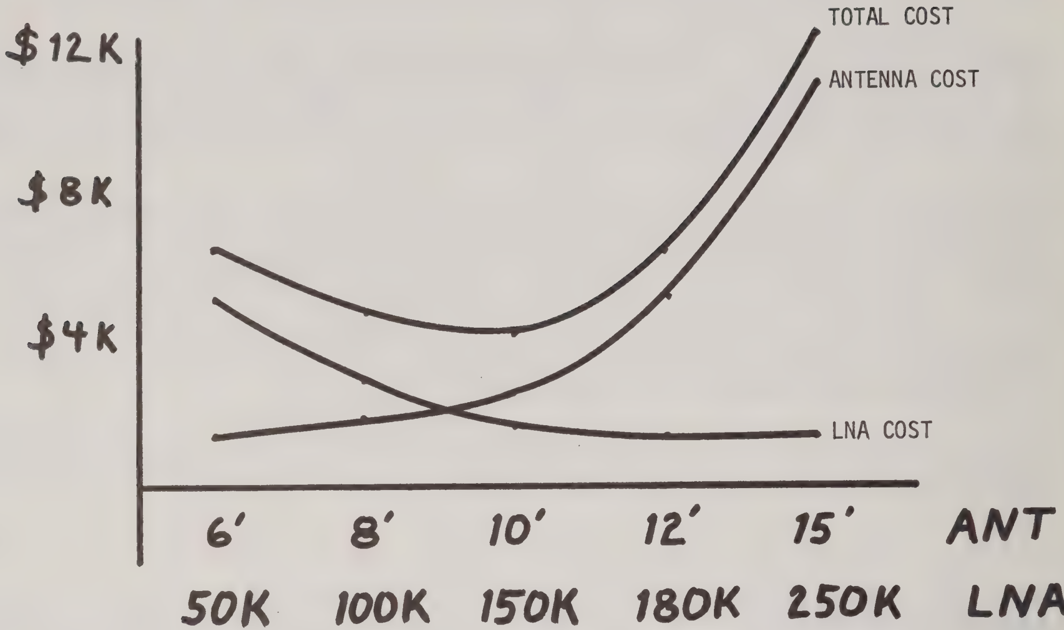

FIGURE 1 - COST EFFECTIVENESS ANALYSIS FOR COMMERCIAL TVRO TERMINALS

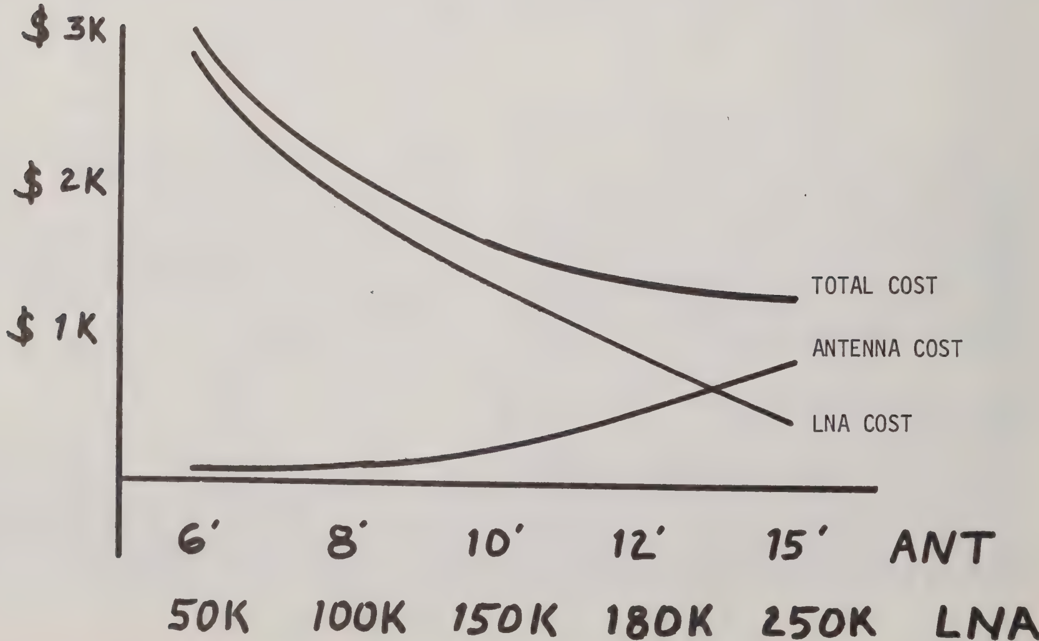

FIGURE 2 - COST EFFECTIVENESS ANALYSIS FOR HOMEBREW TVRO TERMINALS

The top curves in figures 1 and 2 show graphically the tradeoff between antenna size and LNA performance. Note that the total cost curve in Figure 1 bottoms out just about $4K, indicating an optimum combination of a 10 foot antenna and a 150° K LNA. But this only holds for purchased systems, as seen in Figure 2. Here antenna cost doesn't increase nearly as rapidly as LNA cost decreases, for larger antenna installations, and the Homebrew total cost curve optimizes all the way over to the right edge, at about $1200 total cost.

Of course, the numbers are not absolute. The commercial prices are based upon those charged by one particular antenna vendor, and one particular LNA supplier, at a particular point in time. And the costs to build your own antenna or LNA are highly variable, depending upon your own skill, experience, resourcefullness, and yes, luck. Then too, there are a host of other possible combinations to be considered, including Commercial Antenna and Homebrew LNA, Homebrew Antenna and Commercial LNA, cost to modify surplus equipment, etc. Nontheless, these curves will serve as a guide in performing your own cost-effectiveness tradeoff analysis for your particular installation. The main point to be made is that traditional assumtions about LNA cost, antenna size and system performance may or may not be valid in a dynamic industry. A year ago, combining a 10' dish with a 150° K LNA may have bordered on the foolhardy. Today, it seems highly practical, and tomorrow . . . who knows?

Other Considerations

Certainly cost is an important constraint in selecting an antenna/LNA combination for a TVRO terminal. But other, less obvious considerations may be just as crucial. For example, many users who otherwise would have opted for a large antenna, find that the available space, zoning restrictions or what-have-you will only accomodate a somewhat smaller structure. At the other extreme, a small antenna may yield adequate signal strength with a given LNA, but its beamwidth may be so great as to allow co-channel interference from another satellite spaced only a few degrees away from the one of interest.

Countless other constraints will occur to anyone planning a TVRO installation. Each should be evaluated objectively and analytically, prior to ordering any hardware. Nothing is as frustrating as investing several thousand dollars in a system which later proves unsuitable.

Personal Recommendations

Here is where I become totally subjective. Last year I said in print that the optimum private TVRO system would include a 15' dish and a bipolar LNA. Times change, and at this moment I am recommending a somewhat different approach.

In my opinion, one of the best LNA buys on the market today is the Dexcel Corp.* Model DXA-3091. This 30 dB gain, 150° K unit sells for $995 , and will perform adequately on a 10' dish at most North American locations. However, a 12 foot antenna is only slightly more monstrous than a 10 footer, improves system G/T an extra 1½ dB or so, and will help to minimize co-channel interference problems as satellites are parked closer together. And the 12 foot size is well within the capabilities of many a home constructor.[3] Figuring on a homebrew 12 foot dish, the FET LNA mentioned above, $1000 worth of Microcomm conversion modules, and a homebrew baseband unit,[4] it appears feasible to construct a very satisfactory DOMSAT TVRO terminal for about $3K.

* 2285C Martin Ave, Santa Clara CA 95050. (408) 244-9833. Attn: Art Kawai.

The complete TVRO terminal is shown in block-diagram form in Figure 3. With today's satellites, the system affords the private viewer with a wealth of programming for the money!

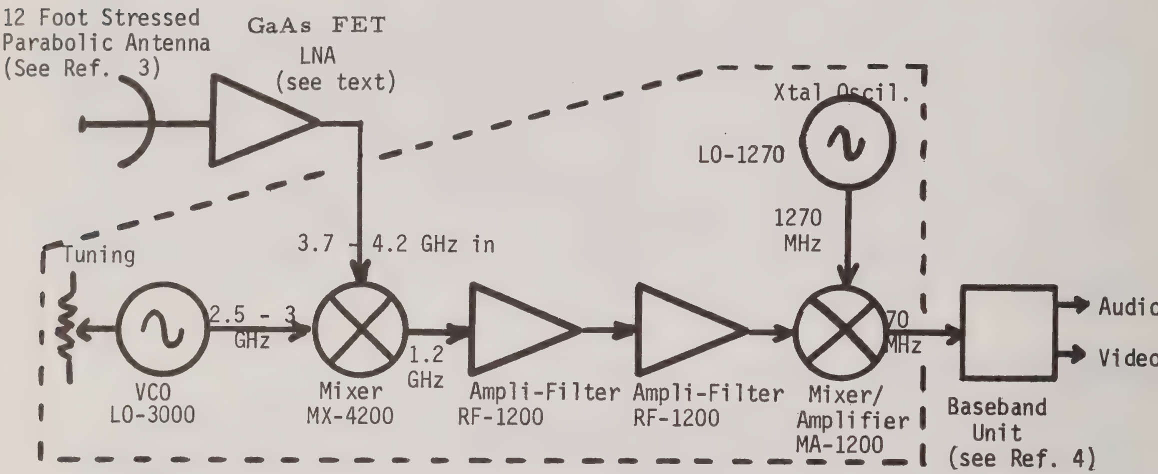

FIGURE 3 - A COMPLETE TVRO TERMINAL WHICH CAN BE BUILT FOR AROUND $3000. For further design details on the modular receiver, send $1 plus a stamped, self-addressed envelope to Microcomm. Request Application Note #8.

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4. Construction details on a fully compatable baseband unit, along with full schematics on the downconverter modules, may be found in the RX-4200 User's Manual, available from Microcomm for $25 in U. S. funds.

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MICROCOMM
Application Note #8
One Dollar

Low-Cost Receiver for Satellite TV

—this modular design uses readily available technology

Author's Note: This article was originally presented by the author as part of the professional program, "Satellite TV and the Private User," at WESCON/79 in San Francisco CA on September 20, 1979. WESCON, the annual Western Electronics Show and Convention, is a large-scale trade show which features films, exhibits, and professional sessions related to all facets of the electronics industry.

The technological revolution which is making possible the distribution of television programming via satellite has been discussed in both popular and technical publications and at conferences and seminars.[1] In this article, I will explore the trade-offs involved in designing a wideband, tunable FM video receiver for processing and displaying DOMSAT (Domestic Communications Satellite) signals.

It should be recognized that there are at least as many conflicting receiver design philosophies as there are microwave engineers, and no claim is made that the concepts presented here are necessarily superior to any other approach. Nevertheless, this receiver does provide adequate performance at low cost, and the trade-offs encountered are typical of those with which others have had to deal. It is hoped that documenting this effort will help to dispel some of the mystique of microwave receiver design.

Video Carrier	
Channels	24
Adjacent channel spacing	40 MHz
Orthogonal channel spacing	20 MHz
Frequency band	3.7-4.2 MHz
Peak deviation	10.25 MHz
Max. video frequency	4.2 MHz
Pre-emphasis curve	CCIR 405-1
Audio Subcarrier	
Frequency	6.8 MHz
Peak deviation	75 kHz
Max. audio frequency	15 kHz
Pre-emphasis time const.	75 usec
Energy Dispersal	
Waveform	Triangular
Frequency	30 Hz
Peak deviation	750 kHz
Composite	
EIRP	+65 dBm
Path loss	−196 dB
99% power bandwidth	36 MHz
Received spectral density	−206 dBm/Hz

Table 1. Typical DOMSAT signal characteristics.

Signal Characteristics

Unlike the vestigial-sideband AM video standard used for terrestrial TV broadcast, DOMSAT video incorporates a wideband FM format, with audio multiplexed onto a subcarrier prior to modulating the composite. The resulting wideband channel (see Table 1) affords considerable "FM advantage" (signal-to-noise enhancement for a given carrier-to-noise ratio); however, the bandwidth and format tend to complicate the receiver design task.

Were a signal consisting of vestigial-sideband AM video with intercarrier narrowband FM audio available from the satellites, receive processing

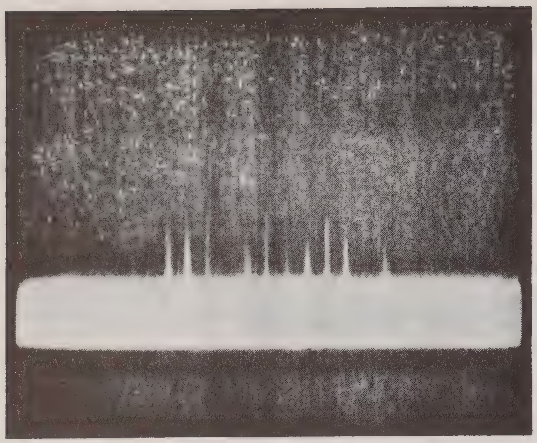

Fig. 1. Spectral display of a 4-GHz DOMSAT downlink recovered on a 4.7-meter antenna and amplified by a GaAs FET Low-Noise Amplifier (LNA). Horizontal deflection is 100 MHz/div, and vertical sensitivity is 10 dB/div. Eleven video carriers, along with their associated FM sidebands, are visible. Note that the fourth channel above the bottom of the band is vacant. Otherwise, channel spacing is 40 MHz and carrier-to-noise ratio appears to be on the order of 10 dB.

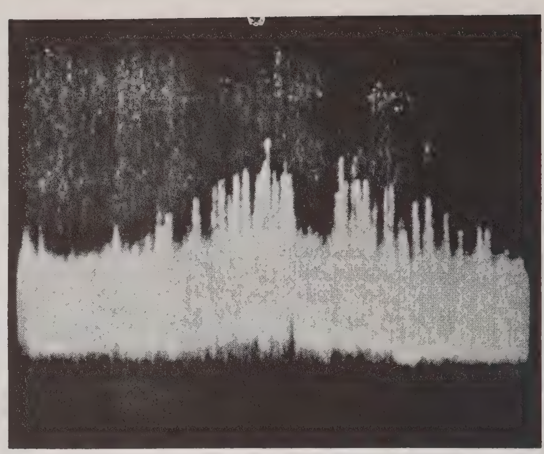

Fig. 2. Spectral display of a single wideband FM video channel after dual-downconversion to a 70-MHz second i-f. Horizontal deflection is 3 MHz/div. and vertical sensitivity is 10 dB/div. This is the composite FM signal from which video and audio are to be demodulated.

would involve merely heterodyning the selected channel in the 4-GHz transmission band against a stable microwave local oscillator (LO), and applying the VHF difference signal directly into the tuner of a conventional TV set. Unfortunately, with DOMSAT signals as they are currently formatted, such a downconversion process would merely spread unintelligible sidebands across six adjacent TV channels.[2] Thus, it becomes necessary to design a complete receiver, including heterodyne conversion stages, demodulators, and video and audio processing circuitry, to recover and display satellite TV.

Frequency Agility

It will be noted from Table 1 that the downlink band used by most North American DOMSATs is 500 MHz wide, and that for a given antenna polarization there will be present up to twelve video carriers, spaced 40 MHz apart (see Fig. 1). That these signals are of extremely low amplitude complicates the design of the Earth station's antenna[3] and low noise preamplifier,[4] but we will assume for the moment that an adequate signal-to-noise ratio exists at the input of the receiver to permit signal recovery. The problem at hand, then, is to select a particular 40-MHz wide channel from among 12 such signals in a 500-MHz wide band, while adequately attenuating the adjacent channels.

A Tuned Radio Frequency (TRF) approach, with detection occurring directly at the downlink frequency, would require readily-tunable bandpass filters of high Q (to accommodate the 1% or so channel bandwidth) and skirts steep enough to reject adjacent channels. Tuning requirements rule out both LC and resonant cavity filters, suggesting the use of Yttrium-Iron-Garnett (YIG) sphere resonators for channel selection.

Although YIG filters can readily be bias-tuned, their cost and the complexity of the required driving circuitry tend to rule them out for private terminal applications. Furthermore, it is far easier to tune a single oscillator than a bank of filters. This suggests heterodyne-downconverting a selected channel into a fixed intermediate frequency, at which demodulation may take place.

I-f Selection

The selection of intermediate frequencies for superheterodyne receivers involves careful attention to the required and realizable mixer bandwidths, image rejection criteria, demodulator circuit capabilities, and tuning constraints. These various considerations tend to be mutually exclusive, but it has been shown[5] that for narrowband systems, a reasonable compromise is achieved by selecting an intermediate frequency approximately one-tenth the frequency of the incoming signal. Although DOMSAT video hardly qualifies as a narrowband service, we can use the one-tenth rule of thumb to establish a starting point. For a 4-GHz input signal, this suggests a UHF i-f. However, the various demodulator circuits compatible with wideband FM video (quadrature detector, ratio detector, Foster-Seely discriminator, phase-locked loop and the like) are all most readily realized in the lower portion of the VHF spectrum. An obvious solution is to utilize dual downconversion, with first and second i-fs near 400 and 40 MHz, respectively.

In fact, numerous experimental DOMSAT video terminals have adopted the above frequency scheme, many employing UHF TV tuners for the second downconversion. The drawbacks to such an approach include the typical UHF tuner's restricted channel bandwidth, relatively high noise figure, and poor local oscillator stability. Nevertheless, when cost is the primary design constraint, these problems can be circumvented.

Not so readily resolved is the input filtering requirement which such a frequency scheme imposes. Assuming low-side first LO injection and top-channel reception, the first conver-

MX-4200 DOUBLE-BALANCED MIXER	
Input frequency	3.7 – 4.2 GHz
LO frequency	2.5 – 3.0 GHz
Intermediate frequency	1.2 GHz
Isolation	20 dB
Conversion loss	7 dB
LO-3000 VOLTAGE CONTROLLED OSC	
Output frequency	2.5 – 3 GHz
Output power	+ 7 dBm
Spurious rejection	20 dB
Tuning voltage range	3 – 10 V dc
Supply potential	+ 13.5 V dc
RF-1200 AMPLI-FILTER	
Center frequency	1.2 GHz
3-dB bandwidth	50 MHz
Gain	15 dB
Noise figure	2 dB
Supply potential	+ 13.5 V dc
LO-1270 LOCAL OSCILLATOR	
Output frequency	1270 MHz
Stability	± 0.001%
Power out	+ 7 dBm
Spurious rejection	40 dB
Supply potential	+ 13.5 V dc
MA-1200 MIXER-AMPLIFIER	
Input frequency	1200 MHz
LO frequency	1270 MHz
Intermediate frequency	70 MHz
Conversion gain	20 dB
3-dB bandwidth	40 MHz
Supply potential	+ 13.5 V dc
Isolation	20 dB

Table 2. Typical parameters for conversion modules.

sion will generate an image frequency which falls a mere 300 MHz below the bottom edge of the downlink passband. An input filter capable of providing adequate passband flatness and minimal insertion loss over the 3.7- to 4.2-GHz band is unlikely to provide adequate image rejection if a 400-MHz first i-f is utilized. One may wish to raise the first i-f high enough to separate the image frequency band well away from the downlink passband, thus simplifying input filtering.

In fact, if the Low-Noise Amplifier (LNA) which precedes the receiver utilizes a waveguide input, then an image filter already exists. Rectangular waveguide is a high-pass transmission line. If low-side first LO injection is used and the first i-f is carefully selected, the LNA's waveguide input will itself reject the image frequency.

Most commercial LNAs utilize an EIA standard WR-229 waveguide input. This guide has a lower $TE_{1,0}$ cutoff frequency near 2.5 GHz. This cutoff frequency is about 1.2 GHz below the bottom edge of the receiver's required passband, so input losses will be minimal. But a first i-f of, say, 1.2 GHz, will place the image frequency as far *below* cutoff as the input passband is *above* cutoff. The image thus ends up quite far down the waveguide high-pass filter's skirts, and may effectively be ignored.

True, the fixed 1.2-GHz first i-f requires that the first LO be tunable, but we mentioned earlier that it's far easier to tune a single oscillator for channel selection than a bank of filters. And even at the top of the downlink passband, where the first LO must be tuned up to 3 GHz, the image at 1.8 GHz is sufficiently far below cutoff so that a 12-cm long input waveguide will afford on the order of 60 dB of image rejection.[6]

Another signpost pointing to the selection of 1.2 GHz as a first i-f is realizable amplifier Q. The 3-dB bandwidth of the i-f amplifier string must be greater than or equal to the 20-dB channel bandwidth in order to avoid unduly attenuating significant sidebands. Assuming a channel bandwidth of 40 MHz and an i-f of 1.2 GHz, this dictates an effective first i-f Q of 30. This value is readily realized with microstripline circuitry.

Despite the obvious economic advantages of the modified UHF TV tuner conversion scheme, it was decided to employ a 1.2-GHz first i-f in the Microcomm DOMSAT video receiver. But what of the second i-f—is it similarly constrained by the wide downlink passband? Actually not. With channel selection occurring in the first downconversion, the second i-f need only be wide enough to accommodate a single video channel. Downconverting the 1.2-GHz first i-f to any desired VHF frequency will allow ample second-conversion image rejection with simple i-f filtering while providing adequate bandwidth to pass the 40-MHz composite.

Since the communications industry has long utilized 70 MHz as a standard i-f for microwave links, it was decided to employ a 70-MHz second i-f in the DOMSAT video receiver. This makes it possible to utilize any of the readily available 70-MHz wideband FM i-f strips to demodulate the video information.

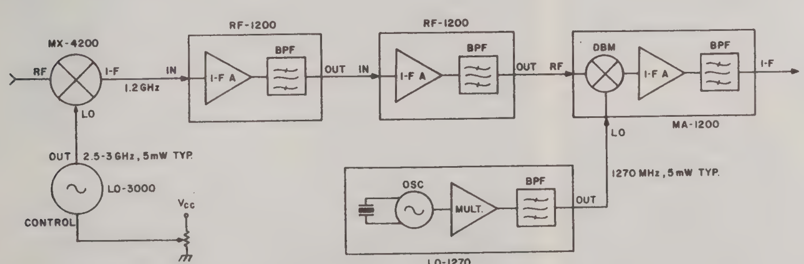

Fig. 3. Block diagram of the heterodyne downconversion portion of the DOMSAT video receiver. Shown at left is the 3.7- to 4.2-GHz input terminal from the LNA and feedline. The 70-MHz i-f output at right feeds the baseband demodulator and processing circuitry (see Fig. 7). The potentiometer shown at the lower left represents the resistive voltage divider which tunes the first LO for channel selection. Gain partitioning of the various blocks is discussed in the text.

Gain Distribution

Gain partitioning for the DOMSAT video receiver depends upon the available power from the satellite, the threshold sensitivity of the demodulator circuitry selected, and the gain of the receive antenna utilized. It has been shown that for the illumination contours typical of most North American DOMSATs, an optimum private-terminal antenna will exhibit on the order of +41-dBi gain.[7]

Given the EIRP and path loss numbers listed in Table 1, it appears that the signal level available to the LNA will be on the order of −90 dBm.

The input threshold for a typical phase-locked loop (PLL) integrated circuit operating as an FM demodulator at 70 MHz is on the order of −20 dBm. This suggests that between the antenna and the demodulator, roughly 70 dB of conversion gain is required.

There are three sources of gain available between the antenna and the PLL. These include the LNA and first and second i-f amplifiers. There are, similarly, three sources of loss in the system: the insertion loss of the transmission line which connects the LNA to the receiver, and the conversion loss of the first and second mixers. For a typical home installation, the feedline insertion loss may be on the order of 6 dB, and if double-balanced diode mixers are used for the two frequency conversions, it is safe to assume that the conversion loss of each will be on the order of 7 dB. This suggests that the overall gain of the LNA, first, and second i-f amplifiers will need to total 90 dB for adequate DOMSAT video reception.

In the interest of maximizing system stability and dynamic range, it is desirable to distribute the required 90 dB of gain uniformly between the rf and two i-f frequencies. A 30-dB gain LNA is clearly feasible at 4 GHz and would require three stages of GaAs FET amplification. This amount of LNA gain is sufficient to adequately mask the noise temperature contribution of the feedline and receiver, allowing the low-noise temperature of the FETs to predominate.[4] Similarly, it is practical to achieve the desired 30 dB of 1.2-GHz gain by cascading two stages of ion-implanted silicon bipolar transistor amplification. At 70 MHz, the required gain is readily available from thin-film wideband gain blocks produced by a number of different vendors.

A block diagram for the dual downconversion portion of the DOMSAT video receiver, partitioned in accordance with the foregoing discussion, is shown in Fig. 3.

Construction of Conversion Circuitry

During the initial system-development phase of any new product, it is common practice to build a number of different amplifier, mixer, filter, and oscillator circuits, each connectorized for coaxial input and output and with each circuit separately boxed and shielded. A modular developmental system provides the engineer with the flexibility of changing one or more circuits without having to disrupt the rest of the system. Microcomm's earlier efforts at modular receiver development have been documented previously.[8]

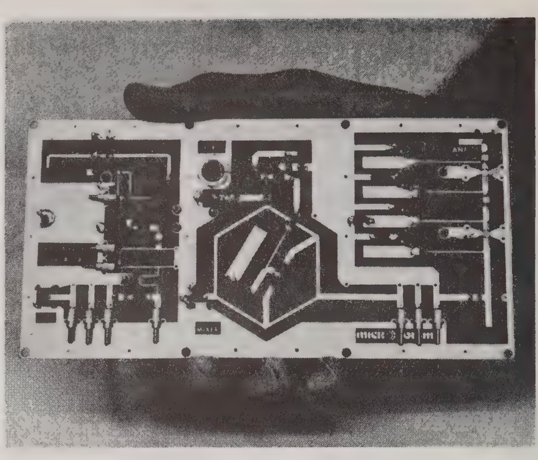

Fig. 4. Typical microstripline circuit module used for satellite video downconversion. Each module in the receive system is mounted in its own shielded enclosure, and all are interconnected via coaxial cable as discussed in the text.

But modularization has advantages for a production system as well. If every function represented by a block in Fig. 3 is implemented in a separate, shielded module, then isolation between stages is maximized and the crosstalk and stability problems associated with stray rf coupling can be eliminated entirely. Further advantages are realized in the area of maintainability. Should a receiver fail, fault isolation by module sub-

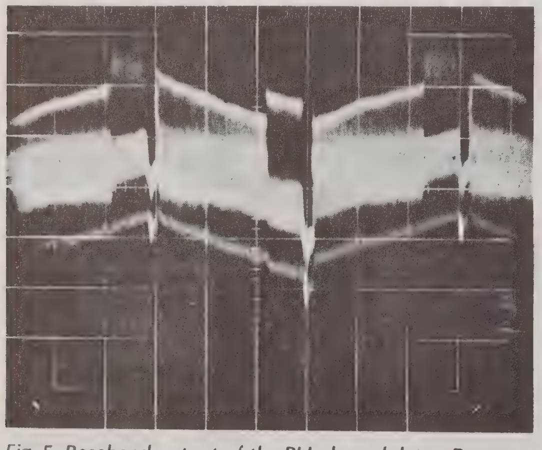

Fig. 5. Baseband output of the PLL demodulator. Presence of the energy dispersal waveform on the video composite is evident.

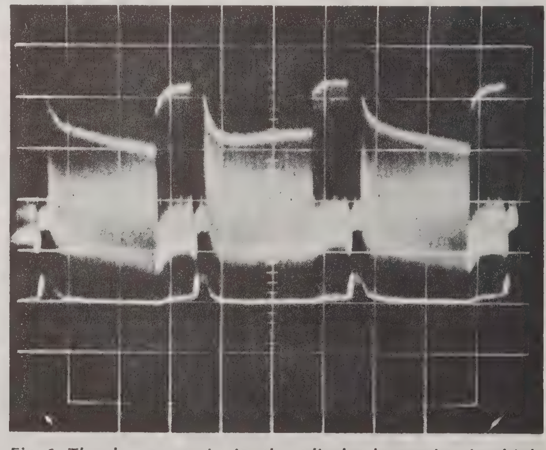

Fig. 6. The dc restorer is simply a diode clamp circuit which removes from the video waveform any vestiges of the energy dispersal waveform seen in Fig. 5.

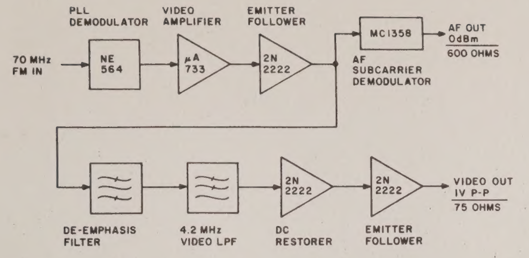

Fig. 7. Block diagram of the complete baseband processing portion of the DOMSAT video receiver. The above circuitry is driven by the output of the downconversion module set (see Fig. 3), and provides standard 1-volt video and 0-dBm audio outputs to an external modulator, studio monitor, or video tape deck.

stitution becomes a viable troubleshooting technique. And, of course, a modular system maximizes user flexibility by allowing customers to assemble from standard modules a custom system designed to meet their precise needs.

The specifications of the modules developed to implement Fig. 3 appear here as Table 2. Each of these modules employs microstripline construction, as shown in Fig. 4, to minimize component count and assure duplicability.[9]

Baseband Processing

Before the wideband FM composite shown in Fig. 2 can be displayed, several processing steps are necessary. The 70-MHz i-f signal will, of course, be demodulated first, and this may be accomplished readily by using a monolithic PLL in a standard circuit.[10] The output waveform from the PLL will contain both the video waveform and the modulated audio subcarrier, but superimposed on these will be found the 30-Hz triangular energy dispersal waveform added to all DOMSAT downlink signals as an interference reduction technique. This waveform is evident in the oscilloscope display in Fig. 5.

Prior to attempting to remove the energy dispersal waveform, it is desirable to amplify the rather feeble video level available from the PLL demodulator, and this may be accomplished using a single monolithic TV video-amplifier IC. Next, an emitter-follower permits splitting off the 6.8-MHz audio subcarrier for demodulation in a standard TV sound i-f microcircuit, whose associated circuitry is modified slightly for compatibility with the higher carrier frequency and peak deviation used on satellite audio.

After passing through a de-emphasis filter and passive video low-pass filter, the video waveform may finally be applied to a diode clamp circuit which will remove the energy dispersal waveform (see Fig. 6). An emitter-follower then establishes the desired 75-Ohm video output impedance to drive recording or display circuitry, as required.

A block diagram for a complete baseband processing subsystem is shown in Fig. 7. This circuit can be constructed on a single printed circuit board and incorporated into a complete DOMSAT video receiver by simply interfacing it to the downconversion circuitry shown in Fig. 3.

Fig. 8. The video output of the baseband unit, displayed on a TV set with the aid of the rf modulator in a video cassette recorder. Most DOMSAT viewers find the clarity and resolution of satellite video clearly superior to network video which is distributed by multiple terrestrial microwave hops.

Display Options

An ideal DOMSAT video receiver for the home Earth-station market would provide an intercarrier audio, vestigial sideband rf output for direct interface to the user's VHF TV receiver. Such an rf output may readily be realized by using any of the available video modulator microcircuits developed for the TV game and home computer industries. In fact, the video and audio levels available from the baseband unit shown here are entirely compatible with such modulators.

Unfortunately, incorporating an rf modulator in a commercial DOMSAT video receiver would subject the entire receiver to FCC type acceptance in the United States. As more than one home computer manufacturer has discovered, the type-acceptance procedure is burdensome in the extreme, with bureaucratic delays often precluding a timely market entry. In addition, the resolution and clarity of most of the available low-cost video modulators leave quite a bit to be desired, and rf modulation would tend to degrade overall video quality noticeably.

A possible solution would be to provide the user with simply a video and audio output from the DOMSAT receiver and allow him to display the receiver's output on a studio-quality TV monitor. However, few videophiles possess such a monitor, and the cost is prohibitive.

Fortunately, most videophiles do possess a videotape recorder (in fact, the owner of a home satellite Earth station would most likely find it impossible to function without one!) and the average video recorder contains an extremely high quality rf modulator. Allowing the user to interface his DOMSAT receiver to the TV via a video recorder provides an ideal solution to the type-acceptance dilemma. And those users who have no recorder are, of course, free to add an external rf modulator, any number of which are available in kit or assembled forms.

Equipment Availability

Once priced in the tens of thousands of dollars, DOMSAT video receivers are now being brought within the reach of the American consumer. The conversion modules shown in Fig. 3, for example, have, since late 1978, been available to the ex-

perimenter at $1000 complete, and to the OEM at significantly lower prices in production quantities.

It is expected that by the end of 1979, a complete, fully tunable DOMSAT video receiver, utilizing the above conversion modules and a baseband unit such as that blocked out in Fig. 7, will be available to the consumer for under $2000. This receiver will be fully packaged and assembled, including power supply, tuner, control circuitry, and inter-connecting cables. Such a receiver promises to make possible for the first time a complete, consumer-grade Earth station, including antenna and LNA, for under $4000. We can only begin to guess at the price breakthroughs which may follow! ■

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